EVALUATION OF VARIOUS CONTRAST MEDIA FOR
RADIOGRAPHIC DEMONSTRATION OF JOINT CAVITIES OF DOGS



by

Faisal Redha Khalid

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## INTRODUCTION

The multitude of joint diseases and the wide diversity of their features have put into the foreground the application of contrast media as a means of confirming an accurate diagnosis in cases of soft tissue lesions of the joints.

The possibility of diagnosis of arthritis through the routine roentgenogram is limited. It is unable to disclose in a large percentage of cases the presence of a torn cartilage and meniscal derangements or interpret with a great degree of accuracy the existence of changes in the synovial membrane. Contrast media, therefore, play an important role in the X-ray interpretation of these lesions. They reveal many pathological cases which under ordinary circumstances show negative radiographic findings.

In human medicine many contrast media have been introduced into the joint cavity, but very rarely has this been done in Veterinary Medicine. Negative contrast media such as air, oxygen and carbon dioxide and positive contrast media, mainly iodine containing media, or both are used to outline the soft tissue structure in the joints. The question of preference depends on how much danger or damage is caused to the joint structures by a particular contrast medium. Therefore, it is very important that contrast media selected for arthrographic purposes should cause minimum irritation, be rapidly absorbed and eliminated, result in the least systemic reaction and give proper details on the roentgenogram.

# REVIEW OF LITERATURE

## Development and Structure of Joint Capsule

In the developing embryo of mammals the mesenchymes in the limb buds are gradually differentiated into two chondrifying elements which are the fundaments of developing cartilage of the bones. The mesenchyme between the segmented chondrification becomes condensed and gives rise to "joint disk".

According to Willis (1940) the cells in the central part of the disk are arranged in arcs and are more compact while the cells in its peripheral region are longitudinal and more loosely dispersed.

The articular surfaces in the developing embryo are present even before the joint cavity appears. Hertwig (1892) arrived at this conclusion which is more reasonable than the concept that the articular surfaces acquire their specific form as a result of muscular activity. As the muscles are not capable of functioning at this time, the movements of the skeletal parts cannot be executed.

According to Gray and Gardner (1943) cavitation in the developing embryo starts at about 8-9 weeks in large joints while in the small joint it may appear even at a later period. They also pointed out that cavities appear small and irregularly traversed by many strands of cells which later disappear, leaving a single cavity.

Hains (1947) arrived at the conclusion that the joint capsule arises from the general mesenchyme. A condensation in general mesenchyme appears around the joint area and he called it "synovial mesenchyme". It is more irregular and vascular than the blastemal interzone. This synovial mesenchyme gives rise to the fibrous capsule, central parts of the synovial cavity, synovia and subsynovial structure.

Ham (1965) stated that the capsule fits like a sleeve over the end of each developing cartilage and extends further to be continuous with the perichondrium surrounding the sides of the cartilage.

As development continues the disk begins to disappear gradually leaving the synovial cavity behind which was formerly occupied by the disk. This phenomenon permits the ends of the two cartilages to come in contact and articulate with each other. The joint capsule becomes continuous with the perichondrium or periosteum. Now the joint capsule is differentiated into two layers. The outer layer is thick and fibrous and the inner layer is membranous, containing the synovial cells and being called the "synovial membrane".

## Joint Capsule

The joint capsule consists of two layers: an outer fibrous layer which is called the fibrous capsule and an inner layer which is called the synovial membrane.

Fibrous layer

The fibrous layer of the joint capsule is continuous with the fibrous layer of the periosteum of the bones that meet at the joint.

Cowdry (1938) described the fibrous layer as consisting mainly of collagenous fibers. He believed their presence here to be mainly to prevent overstretching of the synovial membrane.

Kling (1938) related that the fibrous capsule is not an intact sac. It is missing in some areas so that the synovial membrane rests directly on the fascia, periosteum or fat. In some areas, especially over the tendons, the synovial membrane cannot be separated from the fibrous capsule.

Davies (1948), in his discussion of the joint capsule, asserted that the collagen fibers are relatively inelastic and inextensible and are composed mainly of fibers with few cells, chiefly fibrocytes. The principal component of the fibers in the capsule is the collagen which is characterized by high amino acid content (proline, hydroxyproline and glycine).

Synovial layer (synovial membrane)

The structure of the synovial layer has been studied by Sigardson (1930), Vaubel (1933) and Kling (1938). Sigardson (1930) emphasized that the structure of the synovial membrane is not formed by a distinct membrane but by a modified connective tissue. He also stated that the surface is relatively smooth with a variable number of folds and villi projecting from it.

Kling (1938) pointed out that the most characteristic feature of the synovial membrane is the great difference in structure in different areas. The synovial lining varies from a smooth fibrous surface to a thick layer studded with folds and villi. Histological examination shows marked differences in both cells and subsynovial layer and their arrangements. The cell contents vary from a single row of widely separated flat cells to several rows of cuboid, polygonal, spherical or flat cells closely packed and separated by fine fibrils.

According to Kling (1938), Key (1925) classified the synovial membrane according to the type of subsynovial tissue as follows:

1) The areolar type: covering the parts of the joint subjected to least pressure where the membrane is required to move freely over the fibrous capsule of the joint, e.g., in the suprapatellar pouch of the "knee" joint. The surface cells of this type of synovial membrane usually consist of three or four rows of closely packed cells.

2) The fibrous type: covering the intra-articular ligaments and tendons where the synovial lining

is subjected to pressure. The surface cells are characterized by widely separated cells.

3) <u>The adipose type</u>: covering the intra-articular fat pads. The surface cells are usually formed into a single layer which rests on the adipose tissue. Careful observation reveals that the surface cells are more or less embedded in a thin layer of collagen fibers similar to the surface cells of the other two types mentioned above.

Kling (1938), while referring to Policard (1936), stated that the intercellular stroma of the synovial lining consists of

1) bundles of collagen fibers which are thick in the tendinous areas, loose and of fine texture in the areolar areas, as revealed by Van Gieson stain
2) synovial tissue which has very little elastic tissue as revealed by Weigert's stain for elastic tissue
3) reticular tissue which is abundant in the areolar subsynovial tissue
4) amorphous ground substance, a homogenous substance forming cleft-like spaces that contain fluid in and between the cells and fibers of the synovial stroma
5) lymph follicles which are present in small numbers in the normal subsynovial tissue.

Kling (1938), citing Franceschini (1929-30), stated that the synovial membrane cells of the areolar and adipose areas are of the reticulo-histiocyte type belonging to the reticulo-endothelial system. Further, it was affirmed that these cells are phagocytic and responsible for some biological functions of the synovial membrane, such as absorption.

Key (1932) observed that the synovial cells do not take up large amounts of dye after an intra-articular injection of trypan blue, neutral red and India ink. Therefore, he did not support the idea of Franceschini.

King (1935) was able to demonstrate a Golgi apparatus in the synovial cells of normal human synovial tissue. He further pointed out that Golgi apparatus was less distinct in horse and dog than in human synovial cells.

Synovial villi

King (1935) described the villi as circumscribed outgrowths of the synovial surface varying in size, number and structure according to the species, joint and area.

Kling (1938) stated that in the fibrous part of the synovial membrane they are scanty and small. Over the areolar subsynovial tissue and fat pads numerous villi are found. The villi are usually very cellular and vascular. Kling also mentioned that the surface cells vary from one row of small flat cells to several rows containing spindle and polygonal cells with deep staining nuclei. In these villi, mucin producing cells are frequently seen.

Vascular Supply of the Joint Capsule

Key (1932), Kling (1938), Cowdry (1938) and others recognized that abundant vascular supply and lymph drainage to and from the synovial membrane exist. The branches of arteries that approach a joint usually supply three structures: one to the epiphysis, a second to the joint capsule and a third to the synovial membrane.

Gardner (1948) and Davies and Edwards (1948) studied the rich blood supply of the synovial membrane. Networks are found at the surface of synovial tissue in the areolar areas. Fatty areas lack such capillary networks. Small vessels are uniformly distributed throughout the villi. The fibrous capsule is supplied directly by capillaries passing inwards from longitudinal vessels.

Study of silver nitrate preparations induced Hueter (1886) to assume that vessels can be found on the surface. The so-called "circulous vasculosus articuli" of Hueter (1886) is situated around the articular cartilage. Vessels are very abundant and form loops from which short capillaries project into the cartilage margin.

Kling (1938) pointed out that the synovial membrane of the fat pads is moderately vascular while the fibrous area of the joint is more vascular.

The abundance of blood vessels in the joint has two purposes. First, it supplies the area with the necessary material for elaboration of mucin. Secondly, it helps in dissipation of the heat which is produced during strenuous activity. Bleeding into the joint cavity after irritation, inflammation or even after a minor injury explains the rich supply of blood vessels in the area.

## The Lymphatic Vessels of the Joint

According to Kling (1938), Tillmans (1876) first demonstrated the lymphatics in the joint. He injected a solution of Berlin blue into the knee joints of a dog which was recently sacrificed. By flexing and extending the legs for one hour he was able to detect the presence of the dye in the lymphatic vessels of the synovial membrane. Later he injected the dye directly into the knee joints of horses and described a deep and superficial network of lymphatic vessels under the synovial membrane and a smaller number of lymph vessels near the bones.

Another experiment was accomplished by Kuhns (1938) demonstrating the drainage of lymphatic system of joints and extremities. He injected different mixtures such as

1) India ink in 10% gelatin
2) Prussian blue in 10% gelatin
3) Gerato's mixture (Prussian blue in turpentine and ether)

into subcutaneous tissue and beneath the deep muscular fascia and into the ankle, knee and hip joints of rabbits. He found that both a deep and superficial lymphatic system drained the extremities and the joints were drained through the deep system. He also noted that the injection of 0.5 cc of 20% potassium iodide solution into the joints produced inflammatory reactions on the surface layer retarding the absorbing power of the lymphatics. The lymphatics were obliterated when the inflammation of the synovial tissue was prolonged.

## Nerve Supply of the Joints

Gerneck (1932) did an extensive investigation concerning the innervation of the joints of human feti. He stated that nerves reaching the synovial membrane are ramifications of nerve trunks passing along the joint. He also recognized a great plexus of medullated and non-medullated fibers of different caliber in the cell-poor layer of the synovial membrane. The nerve bundles run an irregular course towards the synovial layer splitting to recombine with the neighboring fibers to form a wide plexus deep in the inner surface of the fibrous capsule. In addition, he described a plexus in the cell-rich region of the synovial membrane. Here the nerve fibers were fine and mostly non-medullated, split and proceeded into the villi. The villi are richly supplied by nerve fibers which form nets and probably free endings. This investigation also noted that the nerves often follow the blood vessels where they appear to give off small bulb-like swellings adjacent to the vessel wall.

According to Hensey (1938), Cda (1935) claimed to have seen sensory elements similar to Pacinian corpuscles in the joint capsule.

Carlton (1934) mentioned that Pacinian corpuscles are sometimes found in the synovial membrane along with fine nerve plexuses.

Davies (1945) stated that the nerve supply of the synovial membrane is relatively scanty. Many of the nerves which enter it are vasomotor in function. Some free nerve endings are present. Pain is a characteristic symptom of joint diseases and it is chiefly attributed to the fibrous capsule.

## Physiology of the Synovial Membrane

According to Gardner (1950), Jaff (1897) and Key (1931) were in accord that there is exchange of molecular and colloidal solutions and particulate matter between the vascular system and the joint cavities. These workers found that molecular solutions diffuse readily through the synovial membrane in the areolar areas of the membrane. Colloidal solutions diffuse through both the areolar and dense areas of the synovial membrane, whereas the particulate matter is taken up by phagocytes.

Kroh (1908) injected potassium iodide and salicylic acid in the joint and demonstrated their presence both in urine and venous blood.

Kellar (1914) noted that absorption from joints affected with chronic synovial involvements took twice as long as did absorption from normal joints, while absorption from acutely inflamed joints was greatly accelerated.

Bywater (1937) in studying metabolic requirements of joint tissues of the horse and rabbit discovered that the synovial villi possess

1) a relatively high glycolytic activity as compared to their oxidative metabolism
2) a metabolism similar to that of osteoblasts
3) glycolytic activity which is greatly increased during the inflammation of the joint
4) glycolytic activity of the cartilage which is lower than that of synovial membrane
5) both synovial membrane and cartilage having dehydrogenase activity, with that of the cartilage being much lower
6) the synovial metabolism of the horse being comparable to that of man
7) the mucin content varying with the viscosity of the synovial fluid.

## The Synovial Fluid

The name synovia [from L. Syn = with, Gr. ovon = egg] is ascribed to Paracelsus (1493-1641) which gives an adequate description of the characteristic sticky and highly viscous nature of normal synovial fluid. The synovial fluid is viscous, colorless or straw-colored and slightly alkaline in reaction.

According to Gardner (1950) the studies of Baur *et al.* (1930) have provided considerable information about the constituents of the synovial fluid. The protein content of the synovial fluid is lower than that of blood serum and averages 1.02 gm/100 cc in cattle, 1.72 gm/100 cc in man. Non-electrolytes, such as urea, uric acid and nonprotein nitrogen, diffuse completely into the synovial fluid. Noncholesterol or fatty acids are present in the synovial fluid. Chloride and bicarbonate are higher whereas Na, K, Ca and Mg are lower in synovial fluid.

Davies (1945) found the composition of the synovial fluid is a dialysate of blood plasma with one added component: its mucosubstances, called hyaluronic acid. This component is also found in the vitreous of the eye and the jelly which forms the bulk of the umbilical cord in the fetus. This mucosubstance is responsible for the physical characteristic of the joints.

Gardner (1950) suggested that probably the only actual membrane from the standpoint of permeability is the endothelial layer of the capillaries. Subsequent diffusion takes place through the connective tissue matrix.

According to Gardner (1950), Joseph et al. (1948) on the basis of electrochemical study of the synovial fluid in dogs reported that the diffusion of most ions is in proportion to their aqueous mobilities and that the inner surface of the joint has little selectivity for these ions.

Davies (1945) found that serum, albumen and globulin are present in the joint fluid. The synovial membrane is more permeable to the smaller albumen molecule so that the albumen-globulin ratio is greater than in serum.

Synovial fluid mucin

Kling (1938) emphasized the importance of synovial mucin. It is the component which gives the synovial fluid its characteristic physical, chemical and biological properties. Mucin distinguishes the synovial fluid from other dialysates. The mucin is mainly responsible for viscosity. The viscosity has been reported by Ropes et al. (1940). They stated that cattle joint fluid had an average relative viscosity of 3.72 while that of human knee joint fluid was 150 at 25 C°.

Davies (1948) showed that there are wide variations between different joints in cattle. He found that the tibio-tarsal joint usually contains a large volume of colorless or pale colored fluid of low viscosity and low nitrogen content. Synovial fluid from the knee joint was colorless to deep yellow with somewhat higher viscosity. The most viscous fluids were found in the axial joints with higher cell counts and higher nitrogen content.

A substance with the properties of synovial mucin is necessary for any mechanical joint. Mucin assists in the maintenance of proper lubrication of the gliding surfaces. Jones (1936) has proved experimentally on the stifle joints of the horse that the coefficient of friction is fourteen times as great when the motion takes place between dry articular surfaces than if it is kept lubricated.

Formation of synovial mucin

The exact nature of the synovial mucin is still a matter of controversy. Fisher (1939) demonstrated the presence of mucin granules in the synovial cells. Kling (1938) described cells staining metachromatically with toluidine blue which he considered to be secretory. Cherry and Ghormley (1938) stained synovial tissue with mucicarmine and claimed to have demonstrated mucin. Davies (1945) was unable to find cells containing either mucin or granules. Key (1932) was not able to distinguish Golgi apparatus in the synovial cells whereas King (1935) described well developed Golgi apparatus. Gardner (1950) had little doubt that synovial cells are responsible for production of mucin. According to Kling (1938), Bianchi (1901) claimed mucin is the degenerative product of the cartilage, based on the similarity of color reaction between cartilage and synovial fluid.

## Cytology of the Synovial Fluid

The cell content of synovial fluid seems to vary considerably from joint to joint and between species. Key (1925) found a typical differential count of the cells in the human synovial fluid: monocytes 58 percent, primitive cells 1 percent, 3 percent synovial cells, 5 percent other blood leukocytes. He also pointed out that the cells increased in size after death.

Sawyer (1963) in his study on the synovial analysis of canine joints found four nucleated cell types: polymorphonuclear leukocytes, monocytes, lymphocytes and clasmatocytes (connective tissue phagocytes). Eosinophils were not observed in his study. Synovial cells were seldom seen. Degenerative nucleated cells were seen in fluids obtained both from normal and pathologic joints.

Table 1 shows statistical analysis of synovial fluid from various normal joints. Table 2 shows statistical analysis of synovial fluid of septic arthritides from various joints.

Table 1. Statistical analysis of synovial fluid from normal carpal, elbow, shoulder, hip, stifle and hock joints[a]

| Analysis | No. of cases | Range | Mean |
|---|---|---|---|
| Amount (cc) | 70 | 0.01-1.00 | 0.24 ± 0.02 |
| pH | 47 | 7.00-7.80 | 7.33 ± 0.04 |
| Leukocytes/cmm in 1,000 | 55 | 0-2.90 | 0.43 ± 0.06 |
| Erythrocytes/cmm in 1,000 | 55 | 0-320.0 | 12.15 ± 6.21 |
| Polymorphonuclear leukocytes (%) | 64 | 0-12.0 | 1.38 ± 0.34 |
| Polymorphonuclear absolute | 47 | 0-32.0 | 3.63 ± 1.22 |
| Monocytes (%) | 64 | 0-96.0 | 39.72 ± 4.09 |
| Monocytes absolute | 47 | 0-838.0 | 23.077 ± 24.80 |
| Lymphocytes (%) | 64 | 0-100.0 | 44.16 ± 3.19 |
| Lymphocytes absolute | 47 | 0-2.436.0 | 245.60 ± 55.29 |
| Clasmatocytes (%) | 64 | 0-68.0 | 4.20 ± 1.17 |
| Clasmatocytes absolute | 47 | 0-166.0 | 14.69 ± 4.57 |
| Mucin clot | 42 | N-F | |
| Viscosity | 53 | N-R | |

[a]Source: Sawyer (1963).

Table 2. Statistical analysis of synovial fluid of septic arthritidis from the carpal, shoulder, hip, stifle and hock joints[a]

| Analysis | No. of cases | Range | Mean | |
|---|---|---|---|---|
| Amount (cc) | 20 | 0.10-1.50 | 0.67 | ± 0.15 |
| pH | 12 | 6.5-7.6 | 7.09 | ± 0.09 |
| Leukocytes/cmm in 1,000 | 17 | 0.27-130.0 | 19.34 | ± 7.40 |
| Erythrocytes/cmm in 1,000 | 17 | 0-282.0 | 62.62 | ± 39 |
| Polymorphonuclear leukocytes (%) | 17 | 1-95.0 | 54.12 | ± 7.40 |
| Polymorphonuclear absolute | 14 | 0-8.170.0 | 15.309.70 | ± 7.498 |
| Monocytes (%) | 17 | 0-30.0 | 7.71 | ± 2.40 |
| Monocytes absolute | 14 | 0-8.170.0 | 1.535.71 | ± 668 |
| Lymphocytes (%) | 17 | 0-95.0 | 23.71 | ± 6.40 |
| Lymphocytes absolute | 14 | 0-9.100.0 | 2.312.79 | ± 689 |
| Clasmatocytes (%) | 17 | 0-80.0 | 14.47 | ± 5.00 |
| Clasmatocytes absolute | 14 | 0-9.100.0 | 1800.64 | ± 760 |
| Mucin clot | 16 | N[b]-V[c] | | |
| Viscosity | 12 | N-R[d] | | |

[a]Source: Sawyer (1963).

N[b] = normal.

V[c] = very poor.

R[d] = reduced.

## Pathology of Synovial Membrane

In the literature covering the subject of the pathological condition of the joints, different opinions are expressed by various authors. Kling (1938) reviewed the anomalies of the synovial membrane which are

1) cyst inside the joint surfaces, probably due to herniation of the synovial membrane outward through the capsule
2) bursal hygroma which is not connected with the intra-articular cavity
3) hypersecretory areas of the synovial membrane accompanied by villous hypertrophy of the inner lining
4) hypersecretory areas which lead to improper lubrication resulting in erosion of the articular cartilage and impaired function
5) mal-development of the vascular and lymphatic nets of the synovial membrane which interferes with nutrition and the removal of colloids from the joints, thereby predisposing the structure to the joint effusion
6) hypertrophy or inflammation of the intra-articular and the peri-articular structure leading to impaired function.

Pomeranz (1933) implied that the first reaction of any joint to either disease or trauma is swelling of the synovial membrane and accumulation of fluid in the cavity.

According to Kling (1938) joints with large secretory areas are less subject to arthritis. Furthermore, the more closely the joint capsule is attached to the tendons the more susceptible the joint is to intra-articular pathology. He inferred that the exudation in the synovial membrane wall and the accumulation of the deleterious metabolites within the cavity obliterates the lymphatics, increases the acidity leading to the precipitation of the blood colloids, thus forming a layer of granulation tissue. At this time the synovial membrane has hypersecretory activity which is most pronounced in moderately mild irritation of prolonged duration. In severe reactions the destruction begins with a pannus and polynuclear and round cell infiltration, and necrosis of the synovial lining occurs. Repair has to take place in the subsynovial tissue with the adhesion being the end result.

Spackman (1936) pointed out that in an acute joint infection there is a separation of articular surface due to fluid from swollen peri-articular soft tissues collecting there.

Irish and Stump (1939) considered the abnormal stress on the synovial membrane produced by the unbalanced distribution of body weight is an important factor in the cause of villus arthritis.

Angevine and Rothhard (1940) found after an experimental streptococcic arthritis in rabbits that the inflammation appears first in the villi and in the ciliary processes of the eye.

Kling (1938) and Wolcott (1927) performed synovectomies on the fat pads of dogs and after sixty days observed entire regeneration of the connective tissue by metaplasia.

Key (1932) implied that the synovial membrane is a connective tissue that is capable of adapting itself to changing mechanical forces.

Ghormley and Deacon (1936) described a typical pannus formation and the changes occurring in different types of arthritis by the use of comparative staining.

## Use of Radiographic Aids in the Diagnosis of Bone and Joint Anomalies

### Dislocation or dysplasia

Hip dysplasia or dislocation of the hip joint    Dislocation of the hip joint is very common in dogs and is occasionally seen in cats.

According to Schales (1956), Henricson and Olsson (1959), Lawson (1963), Hickman (1964), Hoskins *et al.* (1966) and Carlson (1967) this condition is an inherited condition which is transmitted through many generations. Schales (1956) further affirmed that the hip dysplasia gene may come either from the sire, dam or grandparents of the affected dog.

Hoskins *et al.* (1966) stated that congenital subluxation of the hip is very common in larger breeds and is mainly attributed to the shallowness and malformation of the acetabulum. The defect may be either unilateral or bilateral.

In addition, traumatic hip dislocation is not uncommon in dogs. According to Hickman (1964) excessive abduction and adduction of the hip joint cause hip dysplasia in dogs, which is mainly attributed to the rupture of the ligamentum teres (round ligament) and the joint capsule.

Schales (1957) pointed out that hip dysplasia is to be differentiated from "legg-perthes" disease (osteochondritis deformans juvenilis) which is found in breeds with the characteristic straight hind quarters and little rear angulation.

Roentgen manifestation    Lawson (1963) stated that radiographic abnormalities which are present in cases of hip dysplasia are

1) shallowness of the acetabulum giving the head of the femur abnormal position
2) secondary changes developing in the bony structure of the hip joint such as an exostosis on various points of the acetabulum and femoral head
3) new articular surface formation on the acetabulum helping to accommodate the abnormal position of the the femoral head

4) the new change in the acetabular edge which is known as "bilabiation".

Carlson (1967) found the radiographic findings of hip dysplasia in dogs are

1) increased space between the medial side of the acetabulum and the medial margin of the head of the femur
2) uneven joint margin
3) decreased total acetabular rim over the femoral head on the side as compared to the opposite side in the unilateral dislocation.

<u>Elbow dysplasia</u> Elbow dysplasia is commonly encountered in the German shepherd and large breeds of dogs.

Carlson (1967) believed that the condition is congenital and transmitted by heredity. This author in 1961 preferred to use the term "elbow dysplasia" instead of the term "ununited anconeal process" which was used by many authors, since the former term adequately describes the syndrome involving the entire joint.

Hickman (1964) described the elbow dislocation due to trauma, such as automobile accidents, which causes the elbow joint to flex enough to permit the processes anconeus to be detached from the olecranon fossa.

<u>Roentgen manifestation</u> According to Vaughn (1962) radiographically the unattached processes vary in position. It

may appear approximately one-half inch dorsally and partially masked by the distal extremity of the humerus or be separated from its normal situation by a narrow fissure.

Carlson (1967) stated that the Roentgen manifestations are

1) abnormal new bone surrounding the joint margin
2) radiopaque bodies present within the joint
3) slight malformation of the distal extremity of the humerus and proximal ends of radius and ulna with various degrees of osteoporosis
4) articular cartilage involvement causing variable thickness to the joint space
5) development of lesions in advanced cases resembling the hypertrophic degenerative arthritis (osteo-arthritis).

Malformation of the stifle joint

Dislocation and luxation of the patella This condition is often encountered in dogs. Many reasons have been attributed to patellar dislocation in dogs. Kodituwakku (1962) reported a case of patellar luxation caused by rupture of the external lateral ligament. Shuttleworth (1935) concluded that certain numbers of patellar luxation were congenital in origin. Stader (1944) ascribed the tendency of some breeds to have bowlegs with consequent derangement of the perpendicular alignment of the trochlear as a possible cause of recurrent luxations. Hickman (1964) and Carlson (1967) pointed out that the condition is common in small breeds and puppies. Kodituwakku (1962) mentioned also that in cases of intermittent luxations or "recurrent luxations" the patellae were found in the femoral trochlea but would recurrently luxate while the dog is in the process of walking, running or even rising from a recumbent position.

Roentgen manifestation Hickman (1964) found that precise details of this condition can be obtained by radiographical examination. He pointed out that a radiograph taken in a lateral plane will demonstrate the abnormal position of the patella and give an indication of the depth of the trochlea. Antereo-posterior plane with extended joint will reveal any abnormality in the structure of the distal end of the femur and the position of tibial crest.

Carlson (1967) described the radiographic signs as varying from slight abnormality of the trochlear groove to marked malformation of the distal end of the femur and proximal extremity of the tibia. The medial angulation of the distal end of the femur causes medial dislocation of the patella. Atrophy of the muscles of the affected leg is also demonstrated by this method.

Rupture of the anterior cruciate ligament

The cruciate ligaments are two strong bands situated in the intercondyloid fossa of the femur. They lie entirely in the joint capsule, crossing each other between their attachments.

The anterior cruciate ligament arises from the cranial intercondyloid fossa on the tibial spine and is attached to the medial surface of the lateral condyle of the femur while the posterior cruciate ligament is somewhat larger than the former. It arises from the popliteal notch and is attached to the lateral surface of the medial condyle of the femur.

Schroeder and Schnell (1941) asserted that this condition is mostly encountered in those individuals having a defect in the conformation of the stifle joint, the absence of the normal flexion angle in the stifle and tarsal joints which are predisposing factors for the rupture of cruciate ligaments.

Singleton (1961) stated that the rupture of the anterior ligament is more common in dogs than the posterior cruciate ligament.

Schroeder and Schnell (1941) demonstrated that two views, lateral and posterio-anterior exposures, should be taken to reveal the abnormal changes in the joint alignment.

Carlson (1967) indicated that radiography is not an accurate method for examining the rupture of cruciate ligaments but still radiographs can demonstrate the so-called "drawer motion", i.e. sliding back and forth of the tibia on the femur at the stifle joint.

Hickman (1964) stated that the radiologic examination is of little diagnostic value in acute cases, while in chronic cases the degenerative changes which appear as a result of joint disfunction are shown by a decreased joint cavity and osteophyte formation around the margin of the joint.

Meniscal injuries

Normal menisci in dogs consist of semilunar fibrocartilaginous plates with hollowed proximal surface which fits to the condyle of the femur and flat distal surface which fits the tibial condyle. These menisci are retained in position by a number of ligaments. Their main function is to increase the stability of the joint and to diminish concussion.

According to Singleton (1961) meniscal injuries are not easy to recognize. This author also pointed out that the lameness is suddenly established without the history of trauma.

Nilsson (1949), Singleton (1961) and Hickman (1964) agreed that the meniscal injuries are associated with the injuries of cruciate ligaments. They also affirmed that in the chronic cases arthritic changes can be radiographically demonstrated.

Singleton (1961) reported the use of air as contrast medium helps considerably in defining the menisci and cruciate ligament.

Hickman (1964) mentioned that in order to demonstrate the menisci, it is necessary to inject contrast medium into the joint space and for this purpose 15-30 cc of air is the most satisfactory. He further pointed out that injuries to menisci cause their gradual destruction resulting in the development of osteoarthritis.

<u>Roentgen manifestations</u> According to Nilsson (1949) and Hickman (1964) the radiographic findings are

1) reduced joint space
2) lipping of the articular margin
3) osteophyte formation around the periphery of the joint.

<u>Dislocation of the radiocarpal and subluxation of the carpal bone</u>

Dislocation of the radiocarpal joint and subluxation of the individual carpal bones are not uncommon. Radiography is necessary to confirm the diagnosis.

Hickman (1964) and Carlson (1967) reported that dislocation of the radiocarpal joint and fracture of the carpal bones are mainly due to trauma, such as automobile accidents. Carlson (1967) pointed out that normal anatomy should be well-known in such cases and it is recommended that radiographs of the opposite leg should be taken for comparison.

## Malformation of Bones and Joints Due to Nutritional Deficiencies and Metabolic Disturbances

Adequate nutrition is very important for the normal growth of the young and for the maintenance of health of mature animals. Nutritional deficiencies result in many abnormalities, such as malformation of skeletal structure, impaired metabolism and inadequate function of body organs. Campbell (1964) reported that three main types of bone dystrophy occur in animals: osteomalacia (rickets), osteoporosis and osteodystrophia. However, Carlson (1967) described another condition, idiopathic osteodystrophy resulting from nutritional deficiencies.

### Osteomalacia (rickets)

Campbell (1964), Hickman (1964), Hoskins *et al.* (1966) and Carlson (1967) attributed rickets to lowered concentration of calcium and inorganic phosphate in the blood plasma due to a deficiency of vitamin D.

Roentgen manifestation   According to Hoskins *et al.* (1966), Schnell (1940) observed that X-ray examination gives accurate diagnosis of rickets in dogs, where a characteristic mushroom-like appearance or lipping is noticed in the joints.

Carlson (1967) regarded rickets as a lack of calcification of the cartilage arising from the metaphysis at the epiphysial line. The roentgenographic finding is a concave radiolucent area on the metaphysial side of the epiphysial line.

Osteoporosis

Osteoporosis is a term which describes an increased porosity of bones rendering them soft and spongy. According to Campbell (1964) on X-ray these changes result in alteration in the metaphyses. The epiphysial line is normal but an area of decreased density and degeneration can be seen behind this. The slipping of the epiphysis may occur as a result of weakening in the bone structure.

Osteodystrophia

This condition is usually seen in old dogs as a result of renal failure in which the kidney is unable to excrete excesses of phosphorus leading to hyperphosphatemia. This phenomenon tends to cause a fall in blood calcium and stimulates the parathyroid glands causing degenerative changes of osteoblasts and generalized decalcification of bones.

Brodey et al. (1961) have designated the disease as "rubber jaw", "renal osteodystrophy", "renal osteitis fibrosa cystica", "renal hyperparathyroidism", "osteo renal dystrophy", "renal osteomalacia" and "renal rickets".

Roentgen manifestation Campbell (1964) reported the radiographic findings are

1) in severe cases the jaw shows normal teeth having no supporting bony tissue

2) fracture of the jaw.

Hickman (1964) described this condition as "rubber jaw".

Idiopathic osteodystrophy

This condition is encountered in large breeds of dogs during early life. Hoskins *et al*. (1966) stated that the syndrome of the disease develops in growing dogs between four to eight months of age.

Roentgen manifestation According to Carlson (1967) the radiological findings are

1) transverse widening of the metaphysis which shows more density while the epiphysis does not show any increased density
2) roughness and irregularity in the line between the diaphysis and metaphysis.

In addition, the following malformation of bones and joints due to metabolic disorders has also been described by Schnell (1940).

Osteogenesis imperfecta

The condition is seen in puppies and kittens. The essential features appear in long bones where deformity and multiple fractures are seen.

Roentgen manifestation According to Schnell (1940) the radiographic signs are

1) shorter than normal long bones
2) multiple spontaneous fractures detected within the shafts of the bones

3) long bones showing no internal cancellous structure with very thin cortices

4) fractured bones on healing showing no callus formation.

Pathological Changes of the Bones and Joints
Resulting From Infection by Various Organisms
as Evidenced by Radiographic Examination

Infectious arthritis

When a joint is contaminated by bacteria the condition is called "infective arthritis" but when the condition is associated with pus it is called "suppurative arthritis" or "septic arthritis". Hoskins *et al.* (1966) reported organisms responsible for producing infectious arthritis in the dog are streptococcus, staphylococcus and corynebacterium pyogenes. It can also occur by extension from certain septic foci far away from the affected joint region.

Roentgen manifestation According to Holmes (1941) the radiographic signs of acute infectious arthritis are

1) swelling of the soft tissue of the affected joint

2) effusion in the synovial cavity.

In the chronic type of the disease the radiographic signs are

1) decalcification of the articular ends of the bones

2) erosion of the cartilage

3) narrowing of the joint space

4) irregularity in outline of the articular surfaces.

Osteomyelytis

This condition arises from puncture wounds due to trauma, bites or compound bone fractures which cause the organism to gain entrance to the bone where it settles in the lesions.

Roentgen manifestation    Cawley (1961) classified the radiographic signs into four types:

1) Brodie's abcess in which the infection is usually hematogenic and involves cancellous bone. The lesion appears on the radiograph as a circular area surrounded by bone destruction and peripheral sclerosis.
2) Subperiosteal osteomyelytis in which the radiographic signs of the lesion are
   a) new bone formation which is parallel to the original periosteum
   b) the lesion being local and usually involving the endosteum to only a limited extent.
3) Acute medullary osteomyelytis in which the radiographic signs are
   a) necrosis of the medulla of the bone
   b) an area of dead bone
   c) an adjacent living bone becoming osteoporotic
   d) the parallel new bone formation extending over all the cortical surface of the affected bone with irregular thickness; this will not involve

the epiphysis in young animals because of the epiphysial cartilage.

4) Chronic sclerosing osteomyelitis which is an infection of the bone due to fungi and actinomyces causing limited destruction of the cortex of the bone. New bone formation (which is smooth and quite dense) also takes place in such conditions.

<u>Osteomyelytis due to coccidiodomycosis</u>

This condition is different from the osteomyelitis caused by bacteria. According to Reed (1956) the bone lesions due to coccidial infection vary with the location but generally are smooth and firm enlargements. Actual infection of the joint and tendon sheaths is also evidenced by increased amount of synovia from which the organism can be cultured.

<u>Roentgen manifestation</u> Carlson (1967) stated that the radiographic signs for this condition are

1) extensive lesions
2) affected area showing thick new bone formation
3) lesions involving the joints and extending into the joint space.

<u>Hypertrophic pulmonary osteoarthropathy</u>

This condition is commonly encountered in dogs with chronic lung lesions and lung neoplasia.

Cawley (1961) described the clinical signs as consisting of enlargement of the limbs which is not painful on palpation.

Ray and Fisher (1953) found the size of the tumor and the type of malignant cells had no relation to the severity of osteoarthropathy. They also pointed out that joints may be primarily involved with thickening of peri-articular tissue.

Nielson and Bishop (1953) described a case of pulmonary osteoarthropathy associated with chronic bronchopneumonia with bronchiectasis in an old lion.

Roentgen manifestation According to Cawley (1961) the radiographic findings are

1) periosteal new bone production involving the metacarpus or metatarsus and phalanges
2) new bone pertaining to the external surface of the cortex of the affected bone
3) no cortical destruction
4) detectable osteoporosis.

Carlson (1967) explained that the new bone formation is more marked in the dog than in humans. He also pointed out that "clubbing of the distal phalanges" as described in humans is not observed in animals.

## Degenerative Conditions of the Extremities

Hypertrophic degenerative arthritis (osteoarthritis)

Hickman (1964) stated that osteoarthritis results from erosion of the articular cartilage. According to him the two joints commonly affected in dogs are

1) stifle joint, osteoarthritis being mainly due to rupture of cruciate ligament or tearing of meniscus
2) hip joint, osteoarthritis resulting from a disfunction following dysplasia.

Roentgen manifestation Carlson (1967) stated that the radiographic findings are

1) peri-articular lipping
2) narrow joint space
3) "eburnation", subcondral bone density due to cartilage destruction
4) calcified or ossified body within the joint.

Tumors of the extremities

Bone tumors are relatively uncommon in dogs. The majority of bone tumors occurring in dogs are the osteogenic sarcomas. Therefore, it is important to differentiate them from other less serious bone lesions. The tumors which can be radiographically differentiated are classified into three groups:

1) osteogenic sarcoma
2) other primary bone tumors

3) metastatic tumors.

Osteosarcoma (osteogenic sarcoma) Maksic and Small (1959) stated that osteogenic sarcoma generally arises from the metaphysis but seldom from diaphysis.

Cawley (1961) pointed out that the most common sites are the metaphysis of the tibia, femur and humerus.

Owen (1962) stated that all osteosarcomas arise from the endosteum or periosteum of the bone itself.

Carlson (1967) classified the sarcomas by many terms, namely osteolytic sarcoma, osteoblastic sarcoma, osteoclastic sarcoma and osteosarcoma.

Roentgen manifestation According to Maksic and Small (1959) the radiographic findings of the osteogenic sarcoma are

1) early and extensive irregular bone destruction
2) absence of a clearly defined line between the neoplastic and normal bone
3) early rupture of the cortex
4) extensive invasion of the soft tissue
5) "sunbursting", the radiating bony spicules projecting into the soft tissue
6) "Codman's triangle", the triangle or periosteal bone formation
7) metastases commonly resulting from the osteogenic sarcoma.

<u>Other primary bone tumors</u>   Other primary bone tumors involve:

1) Chondrosarcoma: Owen (1962) described one case where the cartilaginous rim of the upper end of the tibia showed destructive changes. The lesion crossed the joint causing complete destruction of the tibia. Destructive changes of the patella and distal end of the femur were also detected radiographically.
2) Fibrosarcoma: According to Owen (1962) early cases fail to show changes in the bone but in advanced stages lesions show a "moth-eaten appearance".
3) Synovioma: This is a malignant tumor which originates from the lining cells of the synovial membrane of the joint or from the bursa. Lieberman (1956) revealed the radiographic findings of synovioma in the elbow joint of dog are
   a) big tumor mass in the elbow joint involving the distal extremity of humerus and the proximal extremities of radius and ulna
   b) widely variable radiographic density of the tumor.

<u>Metastatic tumors</u>   Metastases in bone from primary tumors elsewhere have also been described in the literature.

Owen (1962) described the radiographical signs of a case showing a metastases in the lower end of the humerus arising from squamous-cell carcinoma of the left tonsil in an Alsatian. He stated that there is no elevation of the periosteum. The so-called "sunburst" appearance which is significant in osteosarcoma did not appear in this condition.

It has been recorded by Brodey et al. (1961) that metastases in bone can occur from tumors of the mammary gland, pancreas, tonsil and thyroid.

### Use of Radiologic Diagnostic Agents in Veterinary Radiography

Radiologic diagnostic agents are a group of chemical preparations used for diagnostic purposes in the field of human and veterinary medicine. These diagnostic agents are of two types: 1) radiopaques and 2) radioisotopes. Radiopaques or "contrast media" are characterized by absorption of the X-rays as they pass through the body, whereas radioisotopes emit characteristic radiation which can be detected by radiological methods.

Douglas (1966) stated that absorption of the X-ray beam depends on the thickness, density, and atomic number of the organ or tissue which they penetrate. He further stated that the higher the atomic number of a tissue, the greater is the absorption of the X-ray and, therefore, it is more easily distinguished in a radiograph. Accordingly, the lower the atomic number of the tissue, the lesser is the absorption of X-rays and, therefore, the tissue is not easily distinguished in a radiograph. Contrast media techniques are employed in radiography to overcome the difficulty of demonstration of soft tissue. This can be accomplished by introducing substances of high atomic number, e.g. barium and iodine salts, into or around the organ to be demonstrated.

Strain *et al.* (1964) have mentioned more than 800 known contrast media.

Contrast agents used for routine diagnostic purposes should have the following characteristics.

1) They should not be toxic, irritant, or cause damage to the organ or tissue into which they are introduced.

2) They should offer an accurate outline of the organs to which they are introduced.

3) They should remain in the organ for sufficient time.

Contrast agents are classified in the literature under the following headings.

## Alimentary tract radiopaques

The most common substance used for this purpose is barium sulphate. It is usually given in a colloidal form to reveal the outline of the mucosa of the alimentary tract and is administered orally. The chief disadvantage of barium sulphate is that if it is introduced into the chest through the trachea it will not be absorbed or eliminated and may remain in the chest indefinitely. Douglas (1966) preferred the use of gastrografin, an organic iodine preparation, in cases where there is any risk of this happening.

Water soluble radiopaques

The water soluble contrast media are used world-wide as diagnostic agents. These substances are organic iodine preparations. They are highly water soluble and are rapidly eliminated through the kidneys after they are administered, which can be either orally or by injection. Douglas (1966) stated that these preparations are, in general, local irritants if introduced into any tissue other than the vascular system. Water soluble contrast media are mainly used for investigation of the urinary and the vascular system in veterinary radiography.

Cholecystopaques

These are organic iodine preparations given to the animal either through the alimentary tract or by intravascular injection. These agents are excreted through the liver and by this method the outline of the biliary system can be demonstrated.

Binns (1964) stated that the technique of cholecytography in veterinary radiography could be valuable in investigating cases of obstruction of the bile duct or demonstrating liver displacement associated with the rupture of the diaphragm.

Douglas (1966) indicated that radiographs should be taken 12-15 hours following the administration of the tablets and 30-90 minutes after intravenous injection.

Intravenous pyelography

This method is applied for demonstrating neoplastic or cystic lesion of the kidneys. According to Douglas (1966) the water soluble contrast media are used for this purpose. Preparations such as

sodium acetrizoate ("diaginol", May and Baker)

sodium diatrizoate ("hypaque", Bayers)

sodium mitrizoate ("triosil", Glaxo Laboratory)

can be administered by slow intravenous injection at a dosage of 1 ml per 2 lb body weight for small animals and 1 ml per 4 lb body weight for large dogs. Radiographs are taken 5-10 minutes after administration of the contrast media.

Cystography

Contrast media are employed for demonstration of the urinary bladder to show calculi not visualized by other means, neoplastic lesions of the bladder wall and displacement of the bladder by prostatic enlargement. Contrast media such as inorganic and organic iodine salts can be used. Air is preferable for this purpose. Increased air pressure can also outline the structure of the ureters and of the kidney pelvis.

Myelography

Douglas (1966) stated the difficulties encountered in the use of oily contrast media for the purpose of myelography.

1) Introducing the contrast media directly into the

neural canal has some risk of mechanical damage to nervous tissue.

2) The oily preparations of iodine,

oleumiodissatum ("lipoidol", Bengue)

iophendylate ("myodil", Glaxo Laboratory)

iodetryl ("neo-hydrial fluid", May and Baker)

do not mix with the cerebro-spinal fluid and pass slowly in the spinal canal.

3) These materials are slowly absorbed and may remain within the neural canal for an indefinite time.

4) Being oily preparations these agents have a tendency to globulate and, therefore, lesions may not be outlined distinctly.

Funquist (1962) introduced another method of myelography in dogs which is a water soluble contrast medium called "Kontrast U". This substance is irritating to the nervous tissue. It should, therefore, be administered with local anesthetic (xylocaine). He further stated that the use of a relaxant with general anesthesia is necessary to overcome the muscular spasms. The contrast medium is injected directly into the spinal cord between the fourth and fifth lumbar vertebrae. Radiographs should be taken directly after injection.

Carlson (1967) pointed out that the injection of contrast media into the neural canal may be useful in outlining the intervertebral disc protrusions, damage of the spinal cord, fractures and neoplasms.

Bronchography

This method is applied to outline and detect abnormalities in the trachea and bronchial tree. For bronchography Douglas (1966) recommended the watery form of propyliodone which is marketed as "aqueous dionosil" (Glaxo Laboratories). It is relatively nonirritating, permits adequate radiography, and is eliminated from the lungs in 24 hours.

Douglas and Hall (1959) stated that there is no definite time when the radiographs should be taken following administration of the contrast media, but in order to get desired results it should be carried out within 3-5 minutes after administration. Otherwise the contrast agent tends to accumulate in the alveoli, obscuring the details of the radiographs.

Lymphangiography

Douglas (1966) referred to Hime (1965) and Yeats (1965) who used this technique in animals. Douglas pointed out that "iodetryl" is the most suitable contrast agent employed in this method.

Carlson (1967) showed that two methods can be applied for this purpose. 1) Suitable contrast material is injected directly into the lymph nodes or into the lymphatic vessels. 2) Indirect lymphangiography can be carried out by injecting the contrast agent in the interstitial tissue. It will finally reach the lymph nodes after passing through various lymph vessels of different calibers.

Hysterosalpingography

This method is used to outline the uterus and Fallopian tubes. According to Douglas (1966) the preparation of "iodopyracet" (May and Baker) is the agent of choice. He further stated that 1-6 ml is introduced by means of a catheter passed through the uterine cervix of an anesthetized bitch and radiographs are immediately taken.

Angiography

Angiography is the introduction of water soluble contrast media into the vascular system. At the present time this technique is used more widely in human medicine than in veterinary practice. However, the work of many investigators has shown the value of angiography in veterinary medicine as well.

According to Douglas (1966), Buchanan (1965) stated that angiography can be applied for detecting cardiovascular diseases in animals. Imhoff and Tashjian (1961) pointed out that arterial thrombi in animals can be demonstrated through angiography. James and Hoerlein (1960) found that the use of cerebral angiography was significant in demonstrating neoplasms in the brain.

# MATERIALS AND METHODS

Five dogs weighing 30 pounds each were used in these experiments. Breed, age and sex were not taken into consideration in this study. One joint from each dog was selected for this investigation. Each joint was injected with a specific contrast agent. The following were used:

1) air injected into the stifle joint
2) Hypaque* 25% injected into the shoulder joint
3) double contrast media (negative and positive contrast media) injected into the elbow joint
4) sodium iodide 20% injected into the carpal joint
5) Skiodan** injected into the hip joint.

Each dog was sacrificed after complete absorption of the contrast agent by the joint capsule and to some extent by the articular cartilage. Subsequently, the joints were examined at necropsy and studied for gross lesions. Sections were taken from the synovial membrane for microscopic examination.

Criteria used in evaluating the various contrast media were

1) absence of or degree of discomfort to the experimental subject

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*"Hypaque" (sodium diatrizoates): Winthrop Laboratories, New York, N. Y.

**"Skiodan" (sodium iodomethanesulfonate): Winthrop Laboratories, New York, N. Y.

2) degree of opacity or contrast provided on the roentgenogram

3) length of the post-injection reaction indicating the degree of irritation

4) time required for elimination from the joint cavity.

Care was taken in pneumoarthrography to insure that the following techniques were used.

1) An elastic bandage was applied above the joint to help in keeping the air within the joint capsule.

2) The needle was not handled unnecessarily after it was introduced into the joint, thus avoiding trauma to the synovial membrane, the bony surfaces and the articular cartilage.

3) The desired amount of air was introduced gently into the joint cavity, the quantity being carefully judged according to the size of the joint.

# RESULTS AND DISCUSSION

## Pneumoarthrography of the Stifle Joint in the Dog

### Experimental procedure

One dog weighing 30 lbs was used for this experiment. The area over the right stifle joint was clipped, shaved, and thoroughly scrubbed with antiseptic solution. The animal was given general anesthesia and was positioned in lateral recumbency. An elastic bandage was applied above the joint which helped in getting accurate results. With the stifle joint flexed the patellar ligament was palpated. A 24 gauge needle was inserted into the joint cavity along the medial edge of the patellar ligament near its center, and 30 cc of air was slowly injected into the joint cavity by a syringe.

### Roentgen technique

Immediately after injection the needle was withdrawn and two views were taken:

1) mediolateral view at which the joint was exposed to

K.V.P. 54

mA. 100

Time 1/20 second

F.T.D. 36"

2) posterio-anterior view at which the joint was exposed to

K.V.P. 57

mA. 100

Time 1/20 second

F.T.D. 36"

Observations

Gross examination The injection of air into the right stifle joint produced swelling and local heat. On lightening from anesthesia, the dog was able to feel some pain from the joint. This was significant when slight pressure was applied to the stifle joint. There was no visible skin damage or systemic disturbance. Swelling, heat and pain subsided gradually within a week. The joint appeared normal as evidenced by comparison with the left stifle joint which served as a control.

Examination of the stifle joint at autopsy disclosed no apparent changes or lesions in the intra-articular structures.

Radiological examination Pneumoarthrogram taken in a mediolateral view showed a distended joint capsule. The joint cavity was divided into three well outlined compartments, i.e. suprapatellar pouch, infrapatellar space and the posterior compartment. The infrapatellar fat pad could be seen as stretching across the joint in the infrapatellar space. Medial and lateral menisci were seen. Cartilage and the fabellae were also demonstrated (Figure 1).

Posterio-anterior pneumoarthrograph demonstrated clearly the cruciate ligaments, collateral ligaments, medial and lateral menisci, articular cartilage and femoro-tibial joint space (Figure 2).

Histological findings    Microscopical examination of sections taken from the joint capsule 24 hours after intra-articular injection of air showed no serious reaction except some neutrophilic infiltration in the synovial villi have been detected.

## Conclusions

Pneumoarthrography is the method of introducing negative contrast media into the joint cavity, i.e. air, oxygen or carbon dioxide. According to Dyce et al. (1953) air is preferred because it is a reliable contrast agent, always available and costs nothing.

Sachs et al. (1950) observed that the amount of air used for the inflation of the human knee joint was 80-120 cc where complete distension of the joint cavity was required.

Hickman (1964) stated that good pneumoarthrographs can be obtained by injecting 20-30 cc of air into the stifle joint of the dog.

According to the present study best results are obtained by injecting 30 cc of air into the stifle joint of the dog. Complete distension of the joint cavity has been found to produce obscured outline of the soft tissue structure in the joint cavity.

Bernstein and Arens (1926) found that complete absorption of air from the human knee joint previously injected with air took 12-24 hours. The present study revealed that in the dog a period of approximately six days was required for complete absorption of air from the stifle joint cavity and surrounding soft tissue. (See Figures 3, 4, 5, 6, 7 and 8.)

Dyce et al. (1953) concluded that the cruciate ligaments of the stifle joint in the dog can be demonstrated in the mediolateral pneumoarthrograph which could not be demonstrated in this study. On the contrary the cruciate ligaments were only seen in the posterio-anterior pneumoarthrograph (Figure 2).

On the basis of the present study the contrast medium was found to be of great aid in outlining soft tissues within the joint cavity. These soft tissue structures can hardly be demonstrated in the routine radiograph. Therefore, cases associated with rupture of the cruciate ligaments or injuries of the articular cartilage and the menisci can be easily detected by the presence of the contrast medium in the damaged part of these structures. Accordingly it is also possible to detect the diminution of both the joint space and the synovial cavity in cases of acute and subacute stifle joint infection.

It is obvious that the arthritic bony changes can readily be seen in the routine radiographs but the pneumoarthrogram can reveal other changes such as thinning, thickening, irregularity in contour or break in the continuity of the articular surfaces of the femur, tibia or patella.

## Shoulder Arthrography

### Experimental procedure

One dog weighing 30 lbs was used for this experiment. The animal was anesthetized with "Surital"* (sodium thi-amylal) and positioned in lateral recumbency. The area over the right shoulder joint was clipped and thoroughly scrubbed with antiseptic solution. Then 5 cc of 50% sodium diatri-zoate (hypaque sodium) was drawn into a syringe and was diluted with equal amount of normal saline to make a 25% solution. The shoulder joint was flexed and a 20 gauge needle was directed into the joint using the acromion process of the scapula as a landmark for entering same. The needle was placed ventral to the acromion process and was directed distocaudally through the biceps brachii and deltoideus muscles to the joint space. The 10 cc diluted "Hypaque" was injected into the joint cavity. After withdrawal of the needle the arm was moved to insure homogeneous spread of the medium in the shoulder joint.

### Roentgen technique

One view was taken immediately after the accomplishment of the intra-articular injection with the diluted "Hypaque":

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*Park Davis and Company, Detroit, Michigan.

1) Mediolateral view at which the shoulder joint was exposed to

K.V.P. 72

mA. 100

Time 3/20 second

F.T.D. 36"

Observations

Gross examination No remarkable gross changes were observed after injecting the contrast material into the shoulder joint. Swelling was not marked. Slight temperature difference over the skin of the injected and the uninjected area was noticed which, however, subsided after 24 hours. No difference in rectal temperature was recorded before and after introducing the contrast material into the shoulder joint. Erythema over the joint was not seen. Systemic disturbances or lameness have not been observed in the animal.

At necropsy the shoulder joint was opened. Examination revealed no significant changes in the intra-articular structures except an increase in the amount of the synovial fluid and change in its color (brownish) were observed.

Radiological examination In the mediolateral view the normal arthrogram of the shoulder joint showed that the contrast medium was confined to the joint cavity. The boundary of the joint capsule was distinct. Proximally it was seen to be attached to the rim of the glenoid cavity.

Distally the capsule was attached below the articular area of the humeral head (collum humeri) as seen in Figure 10.

The glenoid cavity and the head of the humerus were covered by a thin layer of the contrast medium. The articular cartilage of both the humerus and the glenoid cavity were well outlined (Figure 11).

The arthrogram also showed the capsule surrounding the tendon of origin of the biceps brachii muscle. The tendon and its synovial sheath extended distally in the intertubercular groove of the humerus where it was held in position by the glenohumeral ligaments (Figure 10).

Histological examination    Sections taken from the joint capsule 24 hours after intra-articular injection of 25% sodium diatrizoate were found normal and did not show any inflammatory reaction.

## Conclusion

The injection of the diluted dye (hypaque sodium) into the shoulder joint showed encouraging results. It was nontoxic, nonirritating and absorbed rapidly from the joint cavity.

In the present study it was found that the required time for complete absorption of the diluted dye from the shoulder joint was two hours. This was evidenced by the arthrograms taken every 30 minutes after introducing the contrast medium into the shoulder joint (Figures 11, 12, 13 and 14).

On the basis of the present study the contrast arthrography should be considered as a useful tool in the study of congenital abnormalities and post-traumatic sequalae of the shoulder joint in the dog. The glenoid cavity and the head of the humerus were well delineated by the contrast medium (Figure 11). Accordingly, congenital subluxation of the shoulder joint which is due to shallowness of the glenoid cavity can be well demonstrated. In case of anterior subluxation of the head of the humerus the distended joint cavity can be easily seen by the aid of the contrast medium. Post-traumatic sequalae which are associated with fractures of the intra-articular structure can be easily seen through contrast arthrography.

Damage of the tendon sheath of the biceps brachii muscle due to trauma causes the contrast medium to leak and spread on the shaft of the humerus. Damage to the areas where the joint capsule blends with the tendons of supraspinatus, infraspinatus and subscapularis muscles will cause the contrast material to spread out into the surrounding tissues.

On the basis of the present study the contrast arthrography is an important adjuvant in the diagnosis of rupture, atrophy and abnormalities of the joint capsule of the shoulder joint.

Pathological conditions such as osteoarthritis, degenerative cases of the cartilage, neoplasm of the synovia and foreign body in the joint cavity of the shoulder joint can be visualized more readily by the help of the contrast arthrography.

## Double Contrast Arthrography of the Elbow Joint

### Experimental procedure

One dog weighing 30 lbs was used for this experiment. After administering general anesthesia the area over the left elbow joint was clipped and thoroughly scrubbed with antiseptic solution.

The dog was positioned in lateral recumbency. The left elbow joint was slightly flexed and the lateral humeral condyle was palpated to determine the site of injection. A 20 gauge 1½ inch needle was placed medial to the lateral humeral condyle. The tendon of the triceps brachii muscle was penetrated at an angle of 45° in order to arrive at the joint cavity.

Five cc of "Hypaque" 50% (sodium diatrizoate) was injected into the elbow joint capsule which was followed by another injection of 15 cc of air. The elbow joint was moved passively to achieve even distribution of the contrast media inside the joint space.

### Roentgen technique

After introducing the contrast media into the elbow joint an X-ray was taken immediately at mediolateral view. The elbow joint was exposed to

K.V.P. 50

mA. 12.5

Time .2 second

F.T.D. 36"

Observations

Gross examination Injection of double contrast media into the joint cavity caused marked swelling immediately around the joint. The injected joint was thoroughly examined after 24 hours. Gross examination revealed marked swelling with local heat. Slight pain on pressure was observed. These local reactions subsided within a period of five days. The right elbow joint served as a control in this procedure.

Lameness, local infection, systemic disturbances, etc. were not evident in this experiment. At autopsy the left elbow joint was opened for macroscopic examination. All joint structures appeared normal except for change in color of the synovial fluid (brownish color).

Radiological examination In the lateral arthrogram of the left elbow joint the joint capsule was clearly demonstrated by the contrast media. On the anterior aspect of the joint the capsule was seen to be extensive and attached proximal to the foramen. On the posterior aspect of the joint the capsule was also seen to be extensive and attached distal to the supratrochlear foramen. The joint capsule inserted between the radial notch of the ulna and the articular circumference of the radius. Caudally the capsule extended upwards beneath the tendon of the triceps brachii (Figure 17).

Histological examination Microscopical examination of sections taken from the joint capsule 24 hours after intra-articular injection of 50% sodium diatrizoate and air showed neutrophilic infiltration, congestion and edema of the synovial villi. Fibrin formation in the joint cavity was also noticed.

## Conclusion

Introduction of the double contrast media into the elbow joint produced satisfactory demonstration of the joint capsule and other associated structures. The joint capsule was found to be distended by the negative contrast medium (air) while the positive contrast medium (iodine containing contrast medium) merely distributed in the joint cavity (Figure 17).

Double contrast arthrography of the elbow joint can be applied for demonstration of some congenital and pathological abnormalities. Congenital abnormalities, such as un-united anconeal process from the dorsal border of the ulna, permits the contrast material to spread in the cleavage line of the anconeal process.

Anterior dislocation of the humerus as a result of a tear of the interosseous ligament, lateral dislocation of the elbow due to disengagement of the anconeal process from the olecranon fossa due to un-united anconeal process or traumatic conditions can be clearly visualized with the aid of contrast material.

Contrast arthrography can also be helpful in diagnosis of some pathological conditions which cannot be easily visualized with the routine arthrogram, such as erosion of the articular cartilage of the semilunar notch of the ulna, new bone formation both on the cleavage line and on the rim of the articular surface of the lateral condyle of the humerus, and inflamed or distended synovial sheath at the origin of the extensor carpi ulnaris muscle.

Intra-articular fractures, such as fractures of the coronoid process and radial head, are well demonstrated by double contrast arthrography.

The arthrogram should be considered to show pathologic changes when the contrast medium is seen outside the limits of the joint cavity. Shape and size of the capsule should be considered when examined with contrast media.

Traumatic conditions which cause damage of the capsule or the collateral ligaments of the radius and ulna and the annular ligament will cause the contrast medium to spread out into the peri-articular tissues. Therefore, double contrast arthrography is significant in finding post-traumatic injuries of the fibrous capsule and the ligaments.

Double contrast arthrography of the elbow joint can also be indicated in suspected cases of degenerative or neoplastic changes which alter the structure of the articular cartilage and synovial membranes.

Osteochondritis can be demonstrated in the routine X-rays if the necrotic fragment is calcified or it becomes a free body in the joint, while with the double contrast arthrography these changes can be easily visualized. The iodine containing contrast medium surrounds the articular cartilage and, therefore, can be used to demonstrate changes in the cartilage.

On the basis of the present study it has been found that "Hypaque" 50% took two hours to be absorbed from the joint cavity (Figures 18, 19, 20 and 21). The time required for the absorption of air was three days (Figures 22, 23 and 24).

Injection of Sodium Iodide into the Carpal Joint

Experimental procedure

One dog weighing 30 lbs was used for this experiment. The animal was anesthetized and positioned in lateral recumbency. The area over the carpus was clipped, shaved and thoroughly scrubbed with antiseptic solution.

The carpus was flexed to open the joint spaces and a 1½ inch 24 gauge needle was pierced through the tendons of the extensor carpi radialis muscle and the anterior surface of the joint. The radiocarpal capsule was reached by directing the needle into the joint space between the distal end of the radius and the radiocarpal bone and 1 cc of 20% sodium iodide was injected into the joint cavity. Another injection was accomplished into the carpometacarpal joint capsule where a 1½ inch 24 gauge needle was penetrated through the overlying tendons between the radiocarpal bone and second and third carpal bones. One cc of 20% sodium iodide solution was injected into the joint capsule.

Roentgen technique

Immediately after the intra-articular injections two views of the carpus were taken, anterio-posterior view and lateral view. In both views the carpal joint was exposed to

K.V.P. 50

mA. 12.5

Time 0.2 second

F.T.D. 36"

Observations

Gross examination Swelling of the carpal joint took place shortly after introducing the sodium iodide into the joint cavities. Twenty-four hours later the swelling was prominent and accompanied by local heat and pain. The animal showed lameness on moving. The swelling subsided gradually within one week and the joint appeared normal. No systemic changes, including body temperature, were noticed.

At necropsy the carpal joint was opened and upon examination the intra-articular structure appeared normal except for an increase in the synovial fluid and a change in its color.

<u>Radiological examination</u> Arthrograms (Figures 26 and 27) showed the sodium iodide was distributed in the radiocarpal capsule surrounding the distal end of the radius and ulna and the proximal articular surfaces of the radialis, ulnar and accessory carpal bones.

The intercarpal joint capsule was seen surrounding the distal articular surfaces of the radial and ulnar carpal bones and the proximal articular surfaces of the carpal bones I, II, III and IV (Figure 28). The carpometacarpal joint capsule was seen surrounding the proximal articular surfaces of the metacarpal bones (Figure 28).

<u>Histological examination</u> Microscopically, sections taken from the joint capsule 24 hours after intra-articular injection of 20% sodium iodide showed severe neutrophilic infiltration, congestion and edema of the synovial villi. Fibrin formation was also seen in the joint cavity.

## Conclusion

The carpal joint in the dog is a composite diarthrodial joint which consists of three small compartments and, therefore, the capacities of the joint capsules are very limited. The fibrous capsule was missing on the anterior surface where the tendons of the extensor muscles pass over the joint. The deep surfaces of the tendons were covered by the synovial layer directly. Thus in the present study it has been found that leakage of the contrast media takes place soon after the injection into the joint capsules. As sodium iodide is irritating to the soft tissue even in low concentrations, swelling of the carpal joint takes place shortly after the injection (Figure 27).

Kling (1938) demonstrated that the absorption of iodized oil from the joint cavity was very slow and, therefore, he pointed out that this substance produced granulocytosis which was later followed by increased lymphocytic infiltration. In the present study the absorption of 20% aqueous solution of sodium iodide took two hours only as evidenced by the radiographs taken every half-hour following the intra-articular injection (Figures 27, 28, 29 and 30). Only slight and temporary swelling and pain were noticed.

Sodium iodide should be used highly diluted as a contrast agent (e.g. 20%). Otherwise it is highly irritating and might cause damage to the surrounding soft tissues.

Valuable information can be obtained about conformation of the joint cavity if used in capacious joints having enough room to allow even distribution of the sodium iodide solution.

The 20% sodium iodide solution can be useful in demonstrating abnormal cases of the carpal joint such as radiocarpal luxation, ulnocarpal luxation, radio-ulno-carpal luxation and carpometacarpal luxation. Post-traumatic sequelae of the carpus associated with fracture of the accessory bone, which is commonly encountered in dogs, can be visualized by the contrast media.

Sodium iodide solution can be applied to confirm the diagnosis of the presence of chip fractures in the joint cavities of the carpal joint. Pathological conditions, such as lysis of a particular bone or the entire carpal joint, can be easily demonstrated by injection of 20% solution into the carpal joint. Neoplasms of the carpal joint of the dog can also be outlined clearly with the aid of the contrast media.

Intra-articular Injection of the Hip Joint with "Skiodan" (Sodium Iodomethanesulfanate)

Experimental procedure

One dog weighing 30 lbs was used for this experiment. The subject was given general anesthesia. The animal was then positioned in lateral recumbency. The area over the left hip joint was clipped, shaved and thoroughly scrubbed with antiseptic solution. The greater trochanter was palpated and a 1½ inch 20 gauge needle was penetrated anterior to the greater trochanter of the femur. The needle was gradually pushed posteroventrally toward the joint space. Injury of the sciatic nerve and damage of the lateral circumflex femoral artery which overlays the joint capsule were avoided with this technique. Synovial fluid was aspirated into the syringe to make sure that the needle was in the joint cavity. Thereafter 5 cc of "Skiodan"* was injected into the joint capsule.

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*Winthrop Laboratories, New York, N. Y.

Roentgen technique

One view was taken immediately after the accomplishment of the intra-articular injection. The following exposures were applied in the radiography.

K.V.P. 74

mA. 100

Time .15 second

F.T.D. 40"

Conclusions

In the ventrodorsal views (Figures 34, 35 and 36) the contrast arthrography of the hip joint showed a clear outline for the following structures:

1) joint capsule

2) acetabulum

3) femoral head and part of neck

4) articular cartilage

5) joint space.

The joint capsule was clearly demonstrated by the contrast material. It was capacious, proximally and attached to the acetabular edge. Distally it was attached to the neck of the femur. Any abnormality in the joint capsule, therefore, can be easily detected on the arthrogram (Figures 34 and 35).

The acetabulum was distinctly demonstrated by the contrast medium. Congenital anomalies confined to the acetabulum such as shallowness of the acetabular cavity, abnormal structure of the acetabulum, and appearance of exostosis on the cranial and dorsal acetabular edge or in the acetabular cavity due to displacement of the head of the femur can be distinctly seen with the help of the contrast medium.

Congenital or traumatic dislocation or subluxation of the head of the femur can be visualized by routine X-ray but examination with contrast material offers more aid in determining the severity of the displacement of the head of the femur.

Valuable information can also be obtained from contrast arthrography concerning the changes which appear subsequent to the dislocation of the hip joint, such as exostosis at the junction of the head and neck of the femur or new bone formation at the line of attachment to the joint capsule.

Contrast arthrography of the hip joint should be considered as a valuable adjuvant in investigation of different pathological cases of the head of the femur. Avascular necrosis of the head of the femur, in which disintegration of the bone cells takes place, can be clearly demonstrated by the contrast medium if a thin layer of the latter is spread on the head of the femur.

Contrast arthrography gives the possibility of outlining variable changes in the head of the femur in legg-calve-Perthe's disease in which distorted lines extend from the head to the neck of the femur. Flattening of the head of the femur and shallowness of the acetabulum which appear later can also be shown.

Osteochondritis desiccans is another pathological condition which can be diagnosed by the contrast medium. In this case an area of bone with its overlying articular cartilage is detached and lies free in the joint cavity. The irregularity of the detached area can be outlined by the contrast medium and the fre[illegible]e in the joint cavity is surrounded by the contrast medium which gives more opaque background on the radiograph.

Intra-articular injection of contrast material into the hip joint helps in revealing cases associated with intra-capsular fracture of the head of the femur or post-traumatic damage of the joint capsule.

Absorption of "Skiodan" from the joint cavity took two hours (Figures 36, 37, 38 and 39). Local or systemic changes were not observed in the animal after the intra-articular injection.

Microscopic examination of sections taken from the joint capsule 24 hours after intra-articular injection of sodium iodomethanesulfanate showed neutrophilic infiltration, congestion and edema of the synovial villi.

## SUMMARY

The purpose of this study was to demonstrate possible uses of different contrast media in outlining the soft tissue structures of the joints in the dog and to confirm their relative values in the diagnosis of certain joint ailments.

Five apparently normal, mature dogs were used in this investigation. One joint of each dog was selected for injection with each specific contrast medium.

### Procedure and Observations

Stifle joint

Air was introduced into the stifle joint. The technique was simple and safe. Filtration of air was not necessary. The following observations were made.

1) It did not produce post injection irritation or other complications.
2) It was capable of producing clearly a shadow of the soft tissue structures of the stifle joint on the roentgenogram.
3) It demonstrated very clearly the size and shape of the normal joint cavity and its pouches: suprapatellar pouch, infrapatellar pouch and the posterior pouch.
4) Further, it was able to cast shadows of both the menisci and cruciate ligaments on the roentgenogram.

5) It was able to detect the infrapatellar fat pad and the patellar ligaments.

6) Time required for complete absorption of air from the joint capsule and surrounding soft tissues was six days.

7) Microscopical examination of sections taken from the joint capsule 24 hours after intra-articular injection of air showed no serious reaction except some neutrophilic infiltration in the synovial villi was detected.

<u>Shoulder joint</u>

A 25% solution of sodium diatrizoate (hypaque sodium) was injected into the shoulder joint. The procedure was accomplished with ease without subsequent complications. The following observations were made.

1) Excellent opacity on the roentgenogram was achieved.

2) The dye revealed the size and the shape of the joint capsule.

3) The articular cartilages of both the glenoid cavity and the humeral head were clearly outlined.

4) It outlined the joint space.

5) It demonstrated the tendon sheath of the biceps brachii muscle.

6) Contrast medium was completely absorbed within two hours following intra-articular injection.

7) Sections taken from the joint capsule 24 hours after intra-articular injection of 25% sodium diatrizoate were found normal and did not show any inflammatory reaction.

<u>Elbow joint</u>

Double contrast media were injected into the elbow joint. The procedure was accomplished by injecting 50% sodium diatrizoate and air into the joint capsule of the elbow. Findings obtained from this experiment were:

1) Air injected into the elbow joint caused distension of the joint capsule thereby producing a uniform surface on the synovial lining. Thus it enabled the positive contrast medium to be evenly distributed on the synovial layer of the joint capsule. Air was also seen to outline parts of the capsule which were not demonstrated by the positive contrast medium.
2) The joint capsule was well demonstrated. Caudally the synovial cavity appeared to extend beyond the olecranon process of the ulna under the tendon of insertion of the triceps brachii muscle.
3) The articular cartilages of the semilunar notch (incisura trochlearis) of the ulna, lateral condyle of the humerus and the proximal articular surface

of the radius (fovea capitis radii) are well outlined by the contrast medium.

4) The anconean process was also outlined by the contrast medium.

5) The joint space was clearly outlined.

6) Sodium diatrizoate took two hours to be completely absorbed from the joint capsule, while air completely disappeared in three days.

7) Microscopic examination of sections taken from the joint capsule 24 hours after intra-articular injection of 50% sodium diatrizoate and air showed neutrophilic infiltration, congestion and edema of the synovial villi. Fibrin formation in the joint cavity was also noticed.

Joint capsules of the carpus

A 20% sodium iodide solution was introduced into the joint capsule of the carpus. The procedure was easily carried out but was followed by some complications. The following observations were made.

1) Due to the structural peculiarity of the carpal joint, sodium iodide leaked out of the joint shortly after injection.

2) Swelling of the carpal joint took place soon after the withdrawal of the needle from the joint capsule.

3) The swelling of the joint and the spread of the

contrast medium outside the joint capsule obscured the details of the soft tissue structures in the joint cavity.

4) The shape and size of the joint capsule were detectable on the lateral view.

5) After partial absorption of the sodium iodide it was possible to observe the contrast medium between the articular surfaces of the bones within the joint capsules.

6) Sodium iodide was absorbed within two hours from the joint capsules.

7) The swelling of the joint subsided within one week.

8) Microscopically, sections taken from the joint capsule 24 hours after intra-articular injection of 20% sodium iodide showed severe neutrophilic infiltration, congestion and edema of the synovial villi. Fibrin formation was seen in the joint cavity.

Hip joint

Sodium iodomethanesulfanate (Skiodan*) was introduced into the hip joint. The method was simple, safe and fairly harmless. No post-injection complication was observed. Findings obtained from injecting Skiodan into the hip joint were:

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*Winthrop Laboratories, New York, N. Y.

1) It outlined the size and shape of the joint capsule.
2) Contrast medium reflected an excellent opacity on the roentgenogram.
3) It outlined the articular cartilages of both the acetabulum and the head of the femur.
4) It clearly demonstrated the joint space.
5) Time required for complete absorption of the dye was two hours.
6) Microscopic examination of sections taken from the joint capsule 24 hours after intra-articular injection of sodium iodomethanesulfanate showed neutrophilic infiltration, congestion and edema of the synovial villi.

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# APPENDIX

Figure 1. Normal pneumoarthrogram of the stifle joint. Lateral view taken shortly after injecting 30 cc of air into the joint cavity. Note the joint capsule is distended. The suprapatellar pouch, the infrapatellar pouch and the posterior pouch are well demonstrated with air. The patellar ligament, the shadow of the infrapatellar fat pad and the menisci are also outlined.

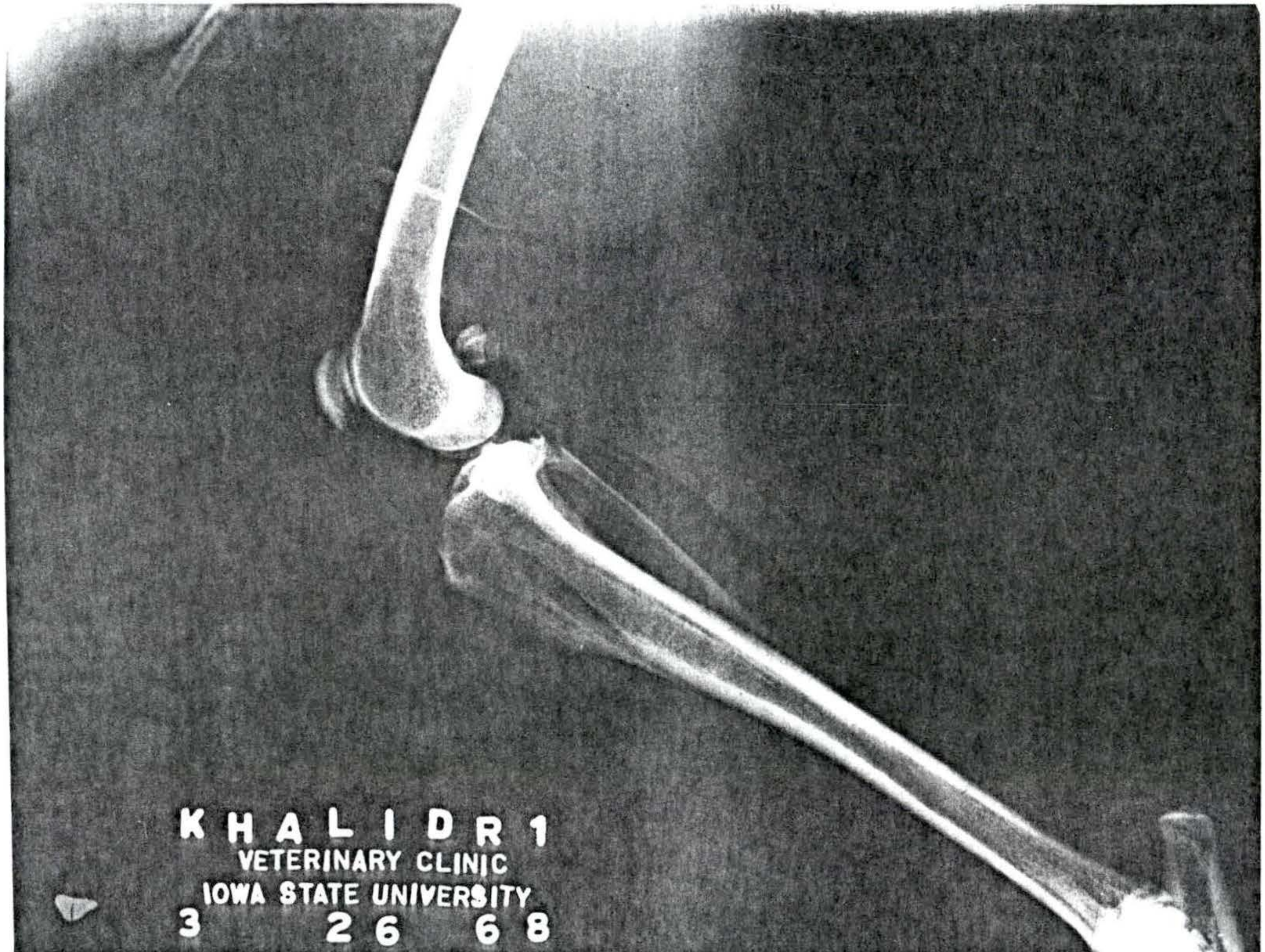
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Figure 2. Posterio-anterior view of the same joint as in Figure 1 showing the lateral and medial menisci, crucial ligaments and the joint space

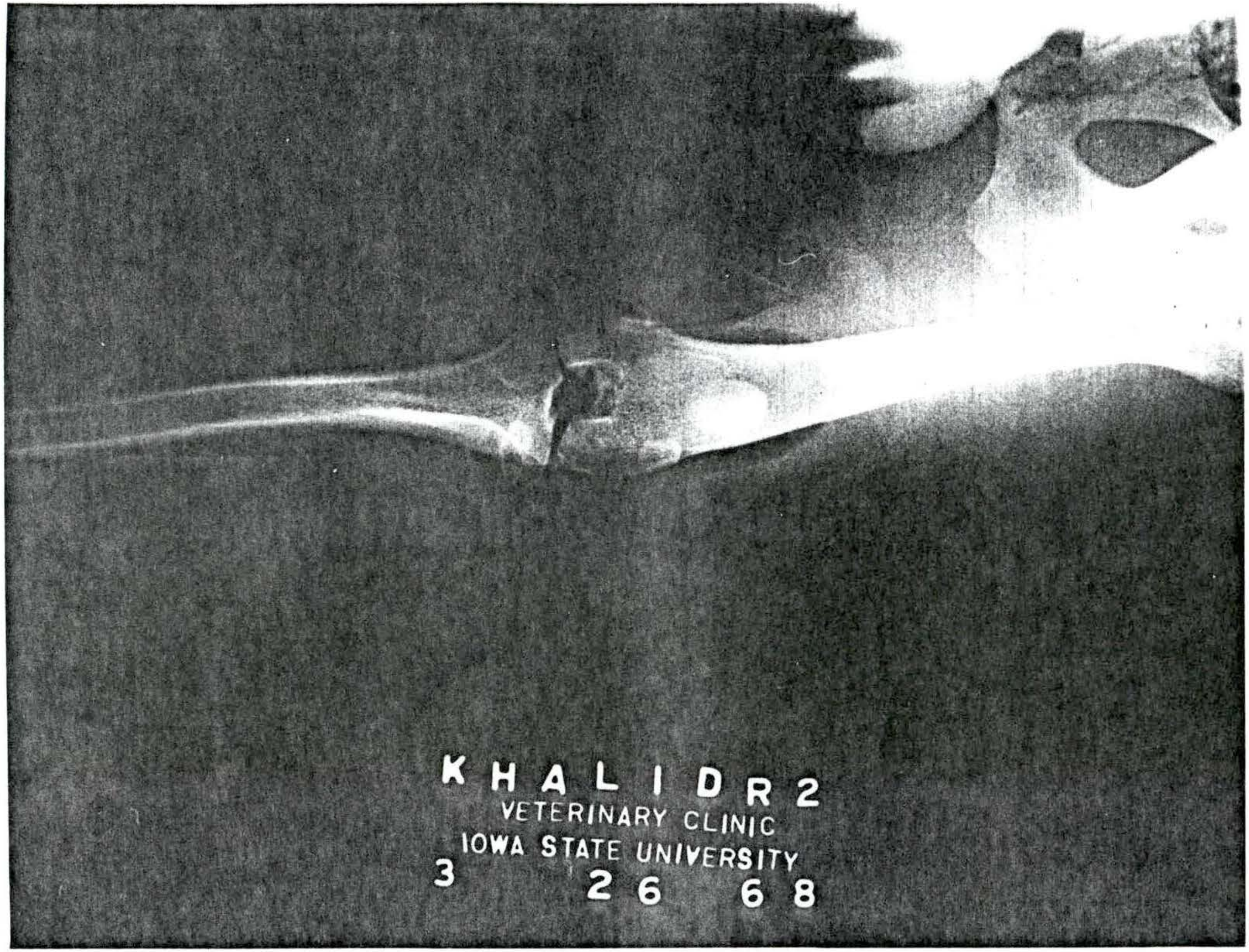
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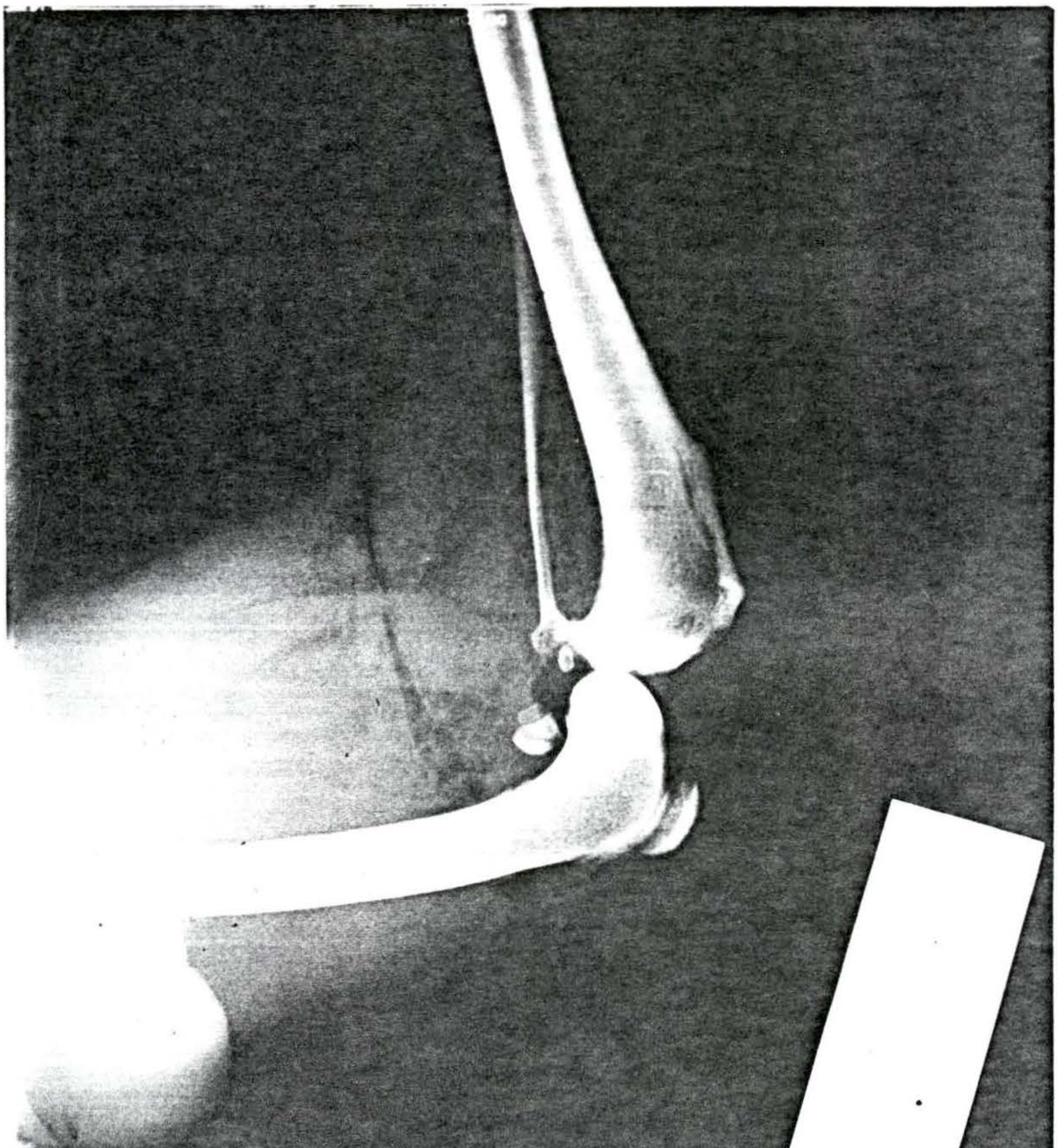
Figure 3. Arthrogram taken 24 hours after air injection into the joint cavity. Note air is partially absorbed from the joint cavity and the surrounding soft tissue.



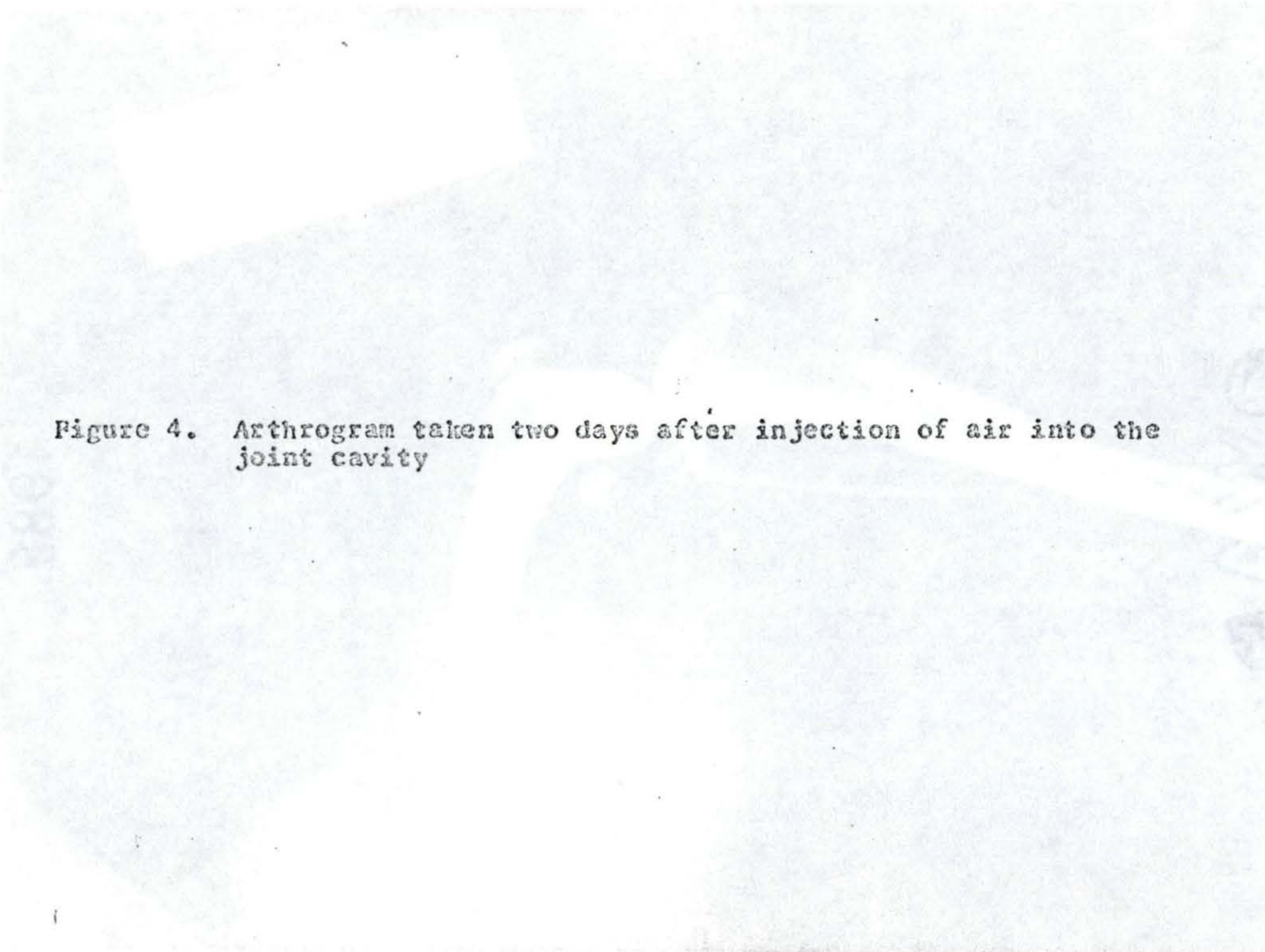
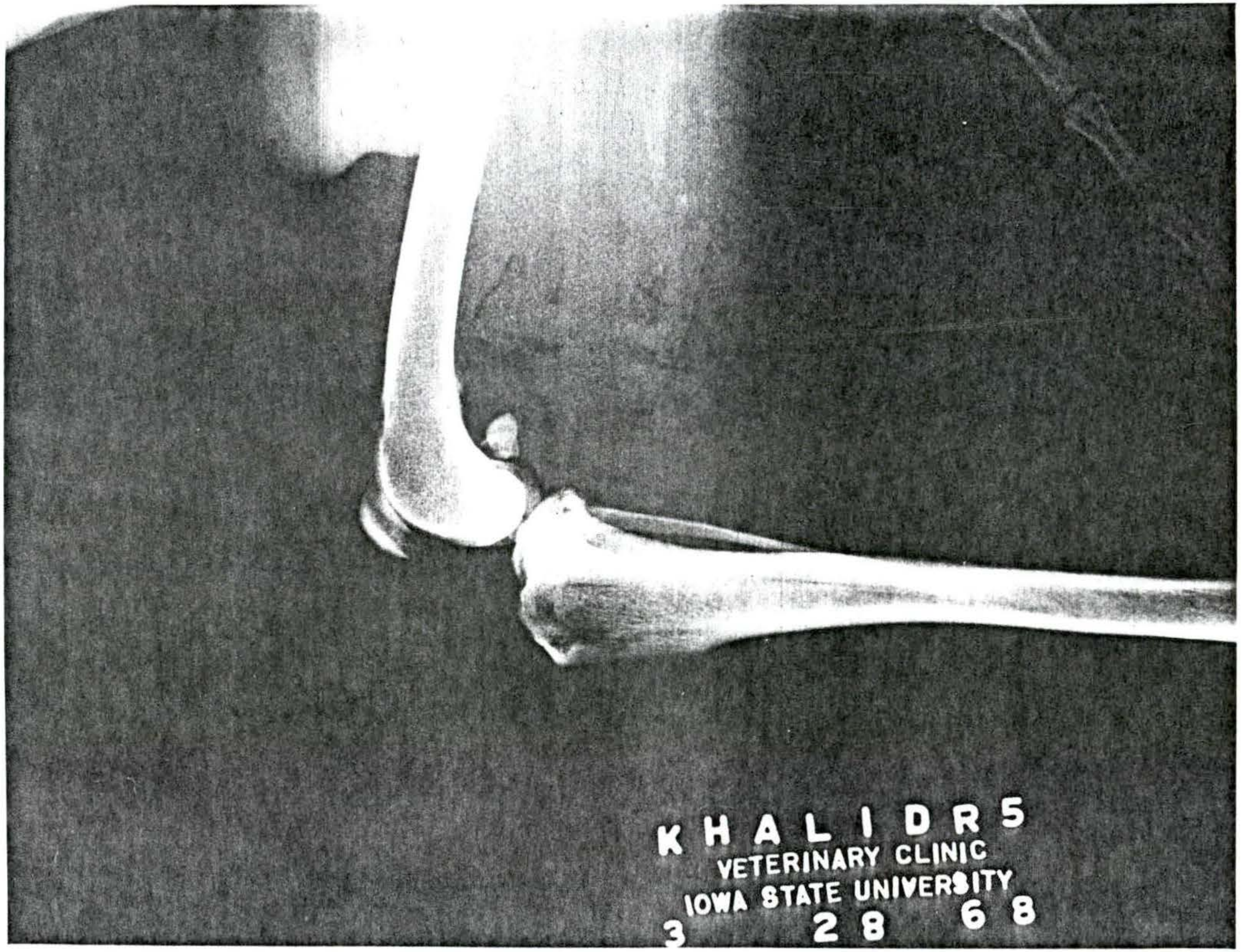


Figure 4. Arthrogram taken two days after injection of air into the joint cavity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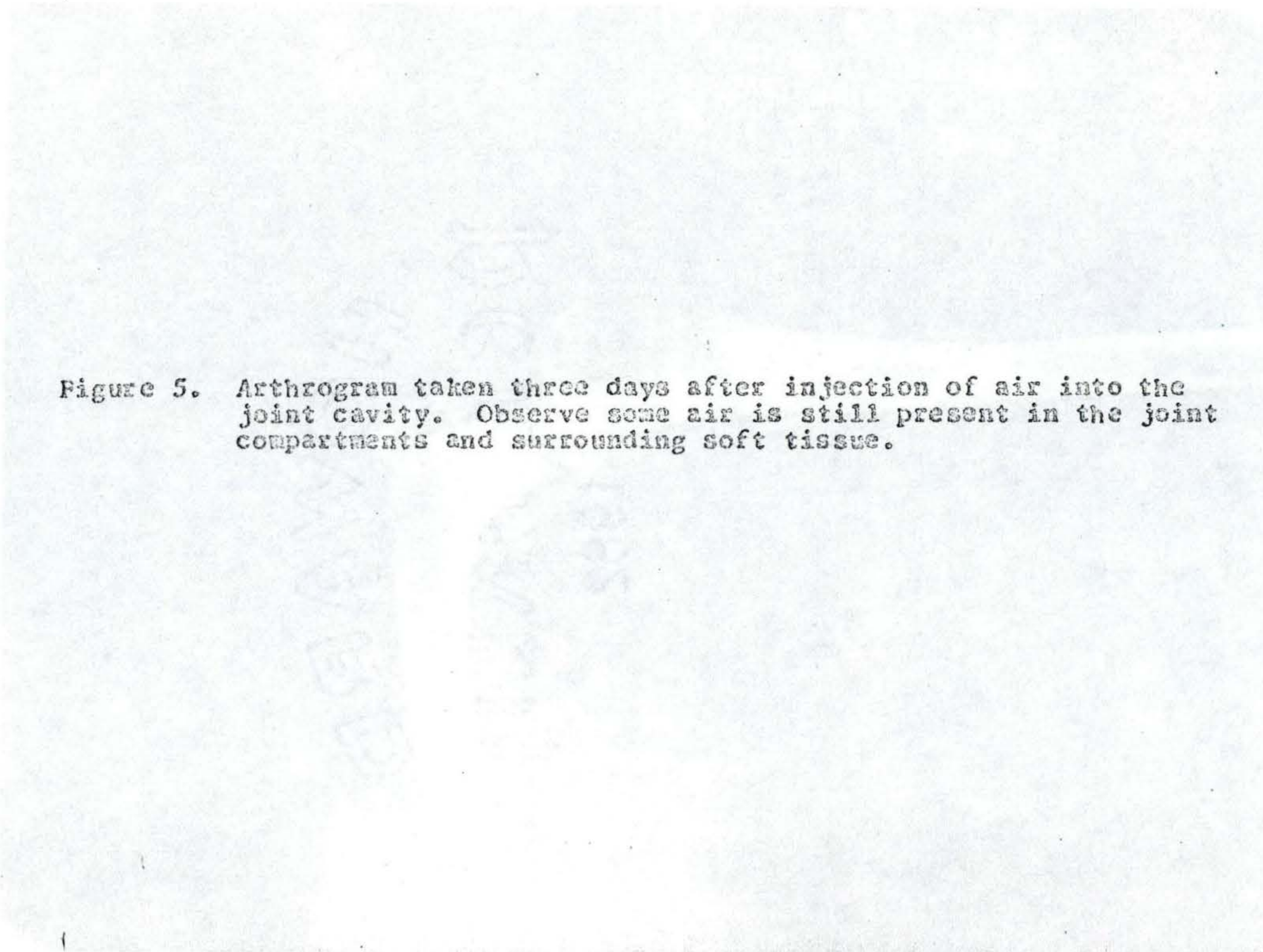

Figure 5. Arthrogram taken three days after injection of air into the joint cavity. Observe some air is still present in the joint compartments and surrounding soft tissue.

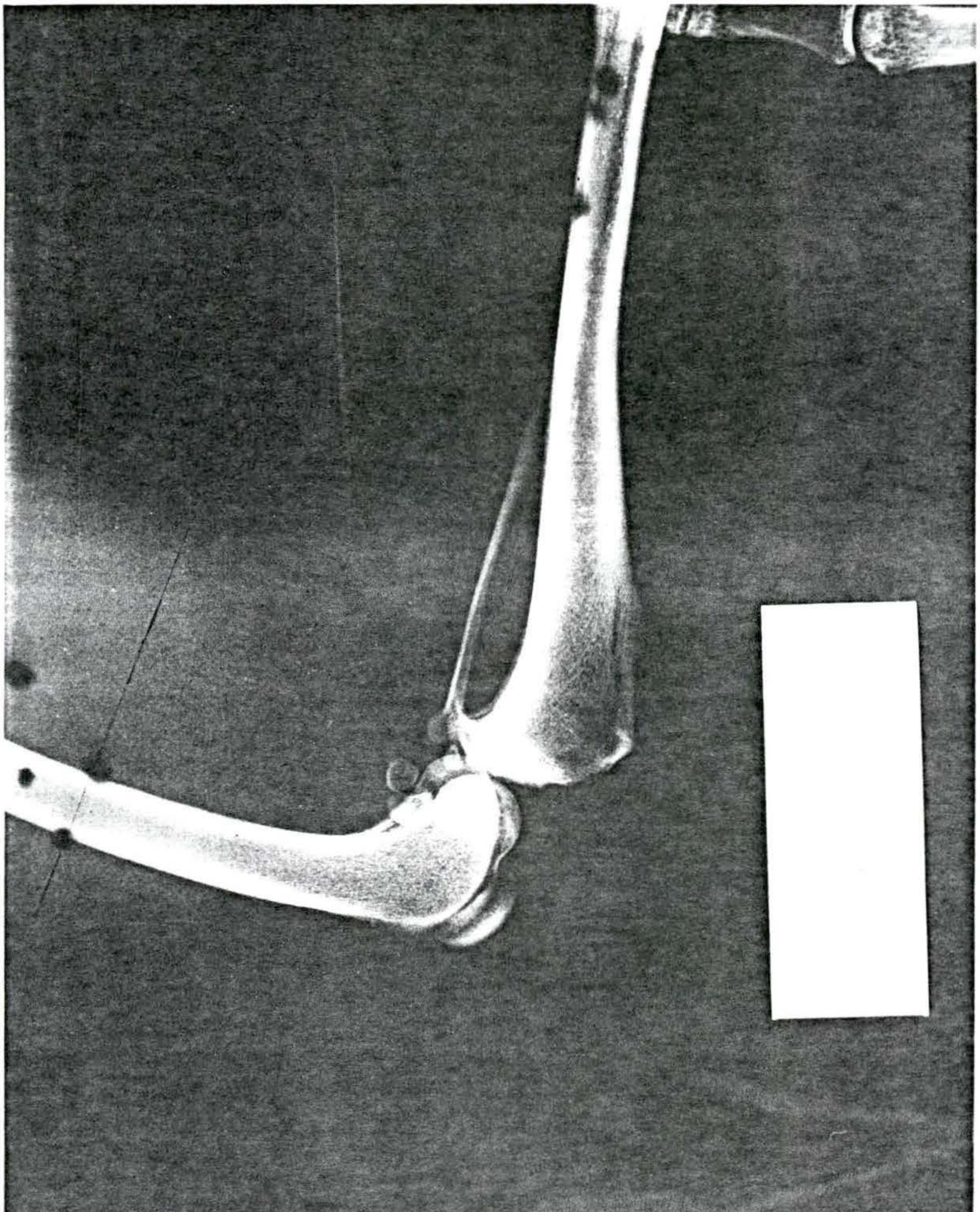

Figure 6. Arthrogram taken four days after injection of air into the joint cavity. Traces of air still can be seen in the joint capsule and surrounding soft tissue.

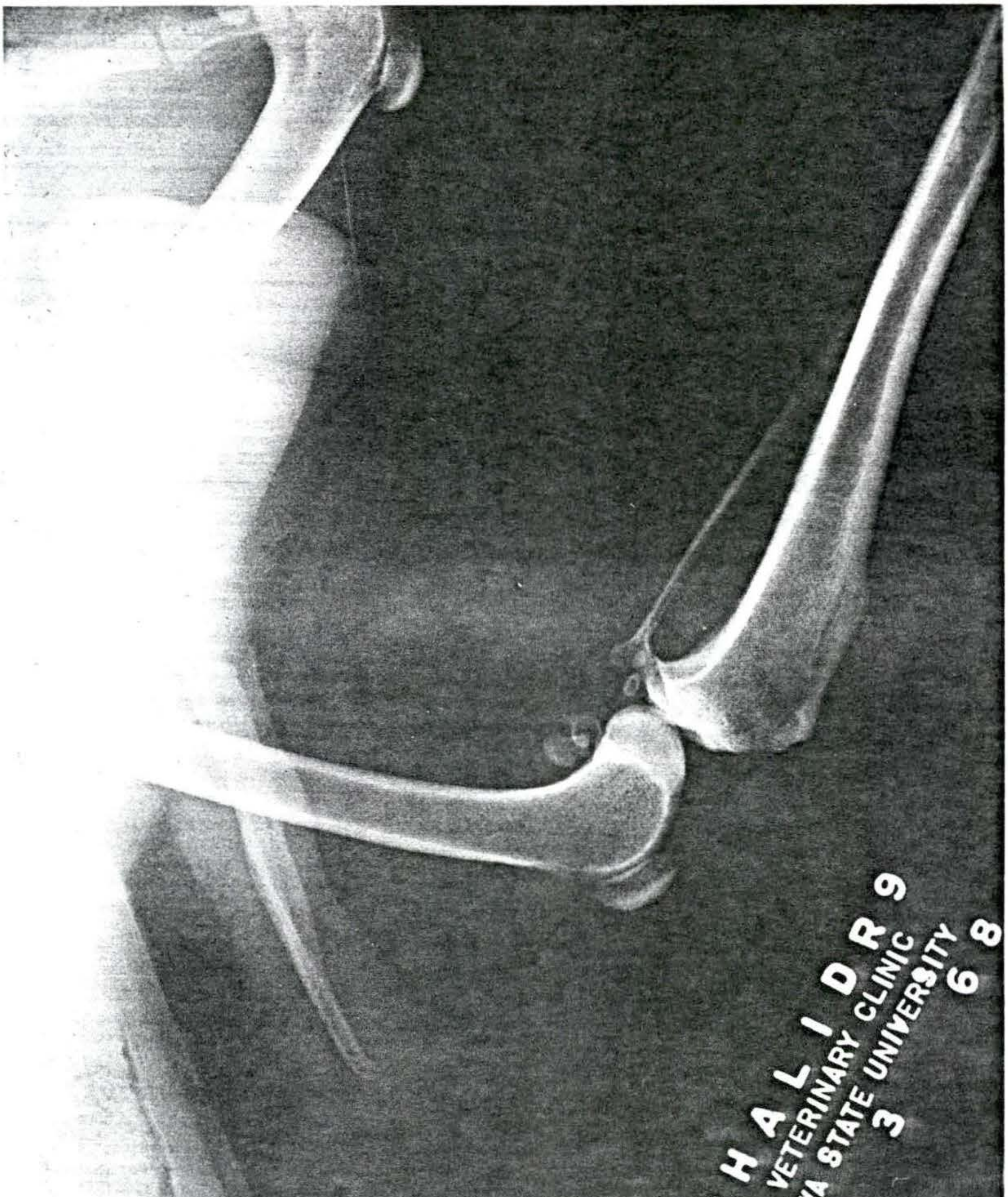
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Figure 7. Arthrogram taken five days after injection of air into the joint cavity. Note air is completely gone from the compartments of the joint capsule but traces of air are still seen in the soft tissue.

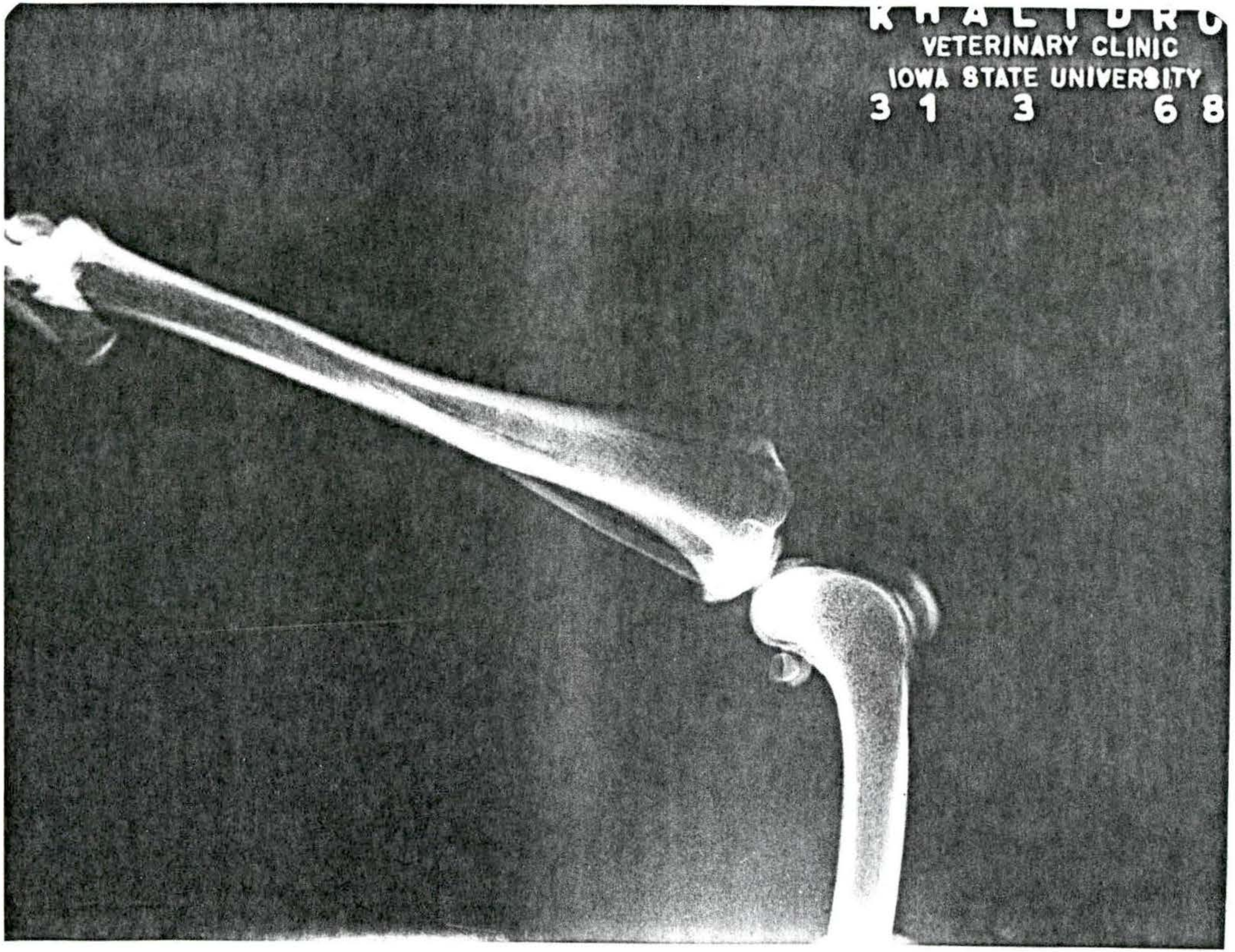
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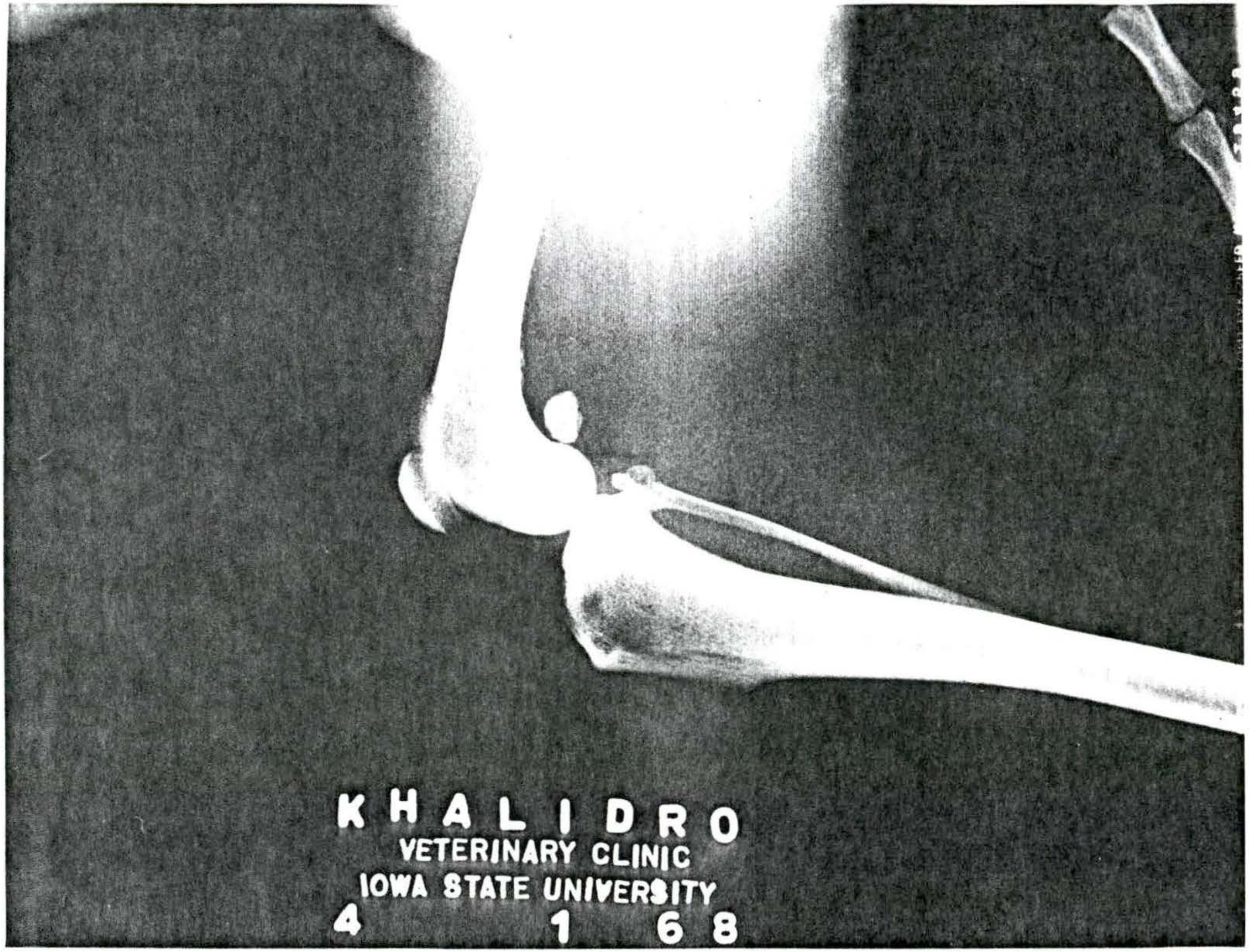
Figure 8. Arthrogram taken six days after injection of air into the stifle joint. Air is completely absorbed both from the joint cavity and the surrounding soft tissue.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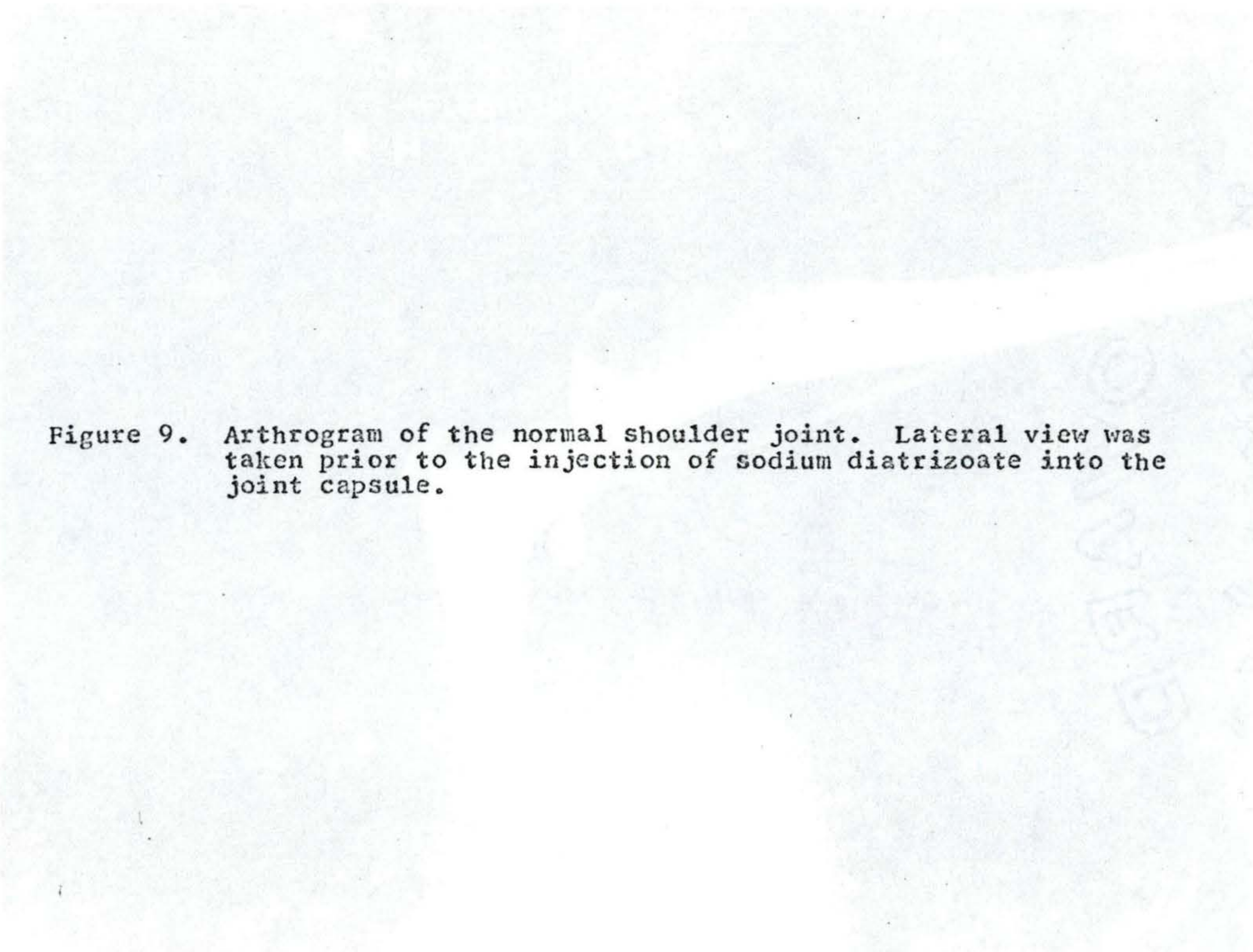

Figure 9. Arthrogram of the normal shoulder joint. Lateral view was taken prior to the injection of sodium diatrizoate into the joint capsule.

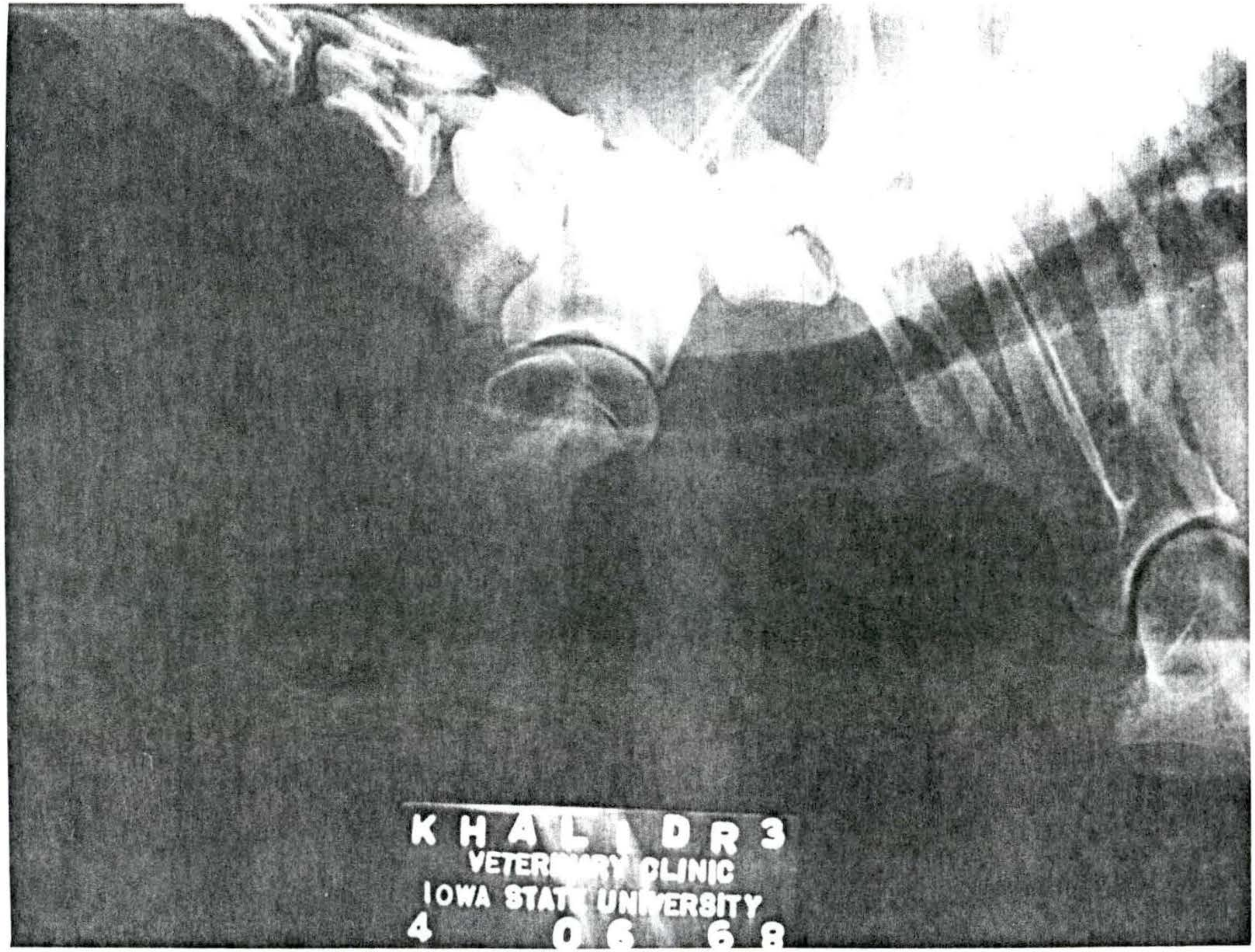
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Figure 10. Arthrogram of the shoulder joint. Lateral view taken shortly after injection of 10 cc of 25% sodium diatrizoate (Hypaque sodium) into the joint capsule. Note the contrast medium fills the joint capsule. The joint capsule is seen to be attached to the rim of the glenoid cavity proximally and distally it is seen to be attached below the head of the humerus. Observe the extension of the tendon sheath of the biceps and its attachment to the neck of the humerus is clearly seen.

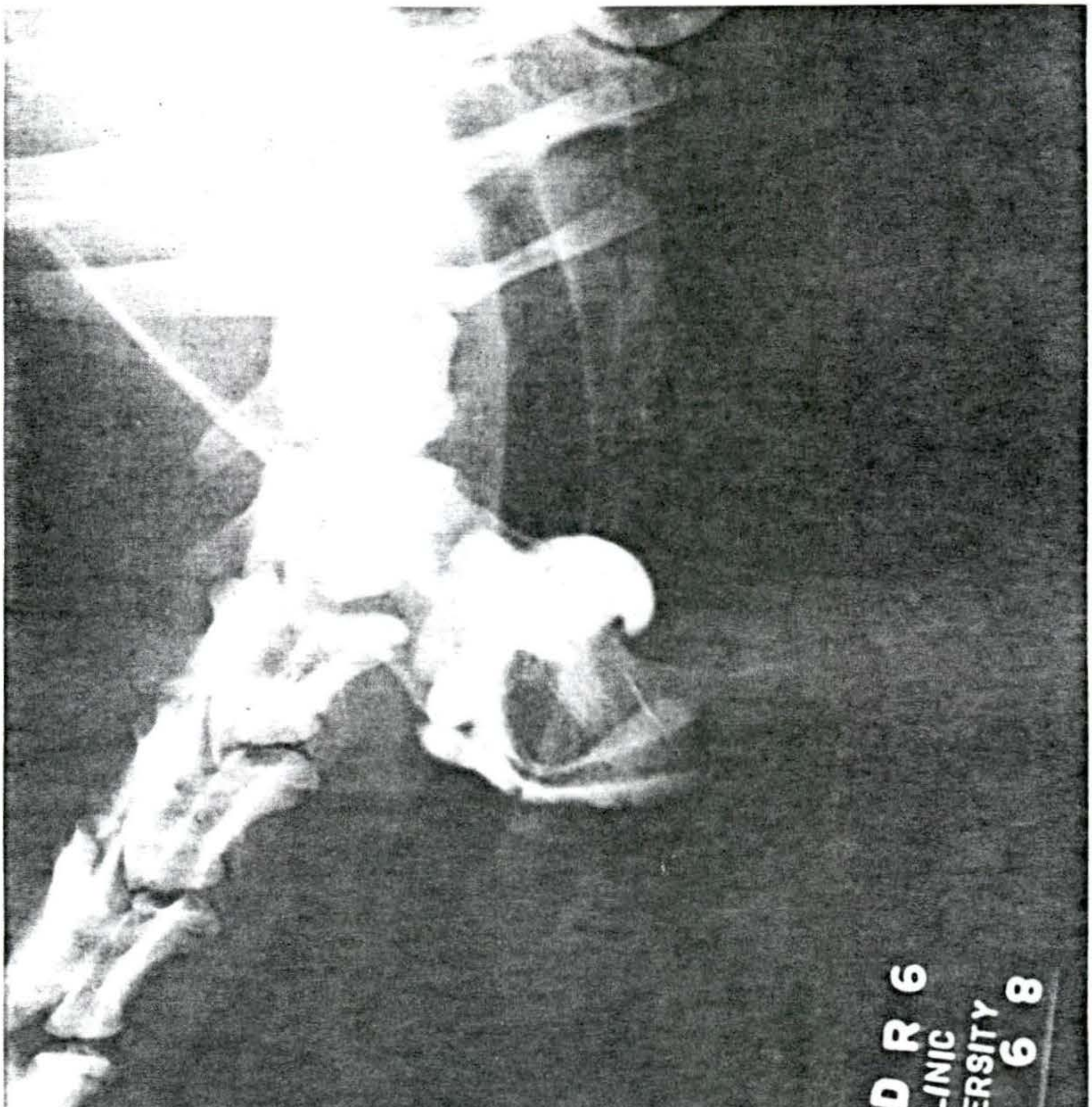
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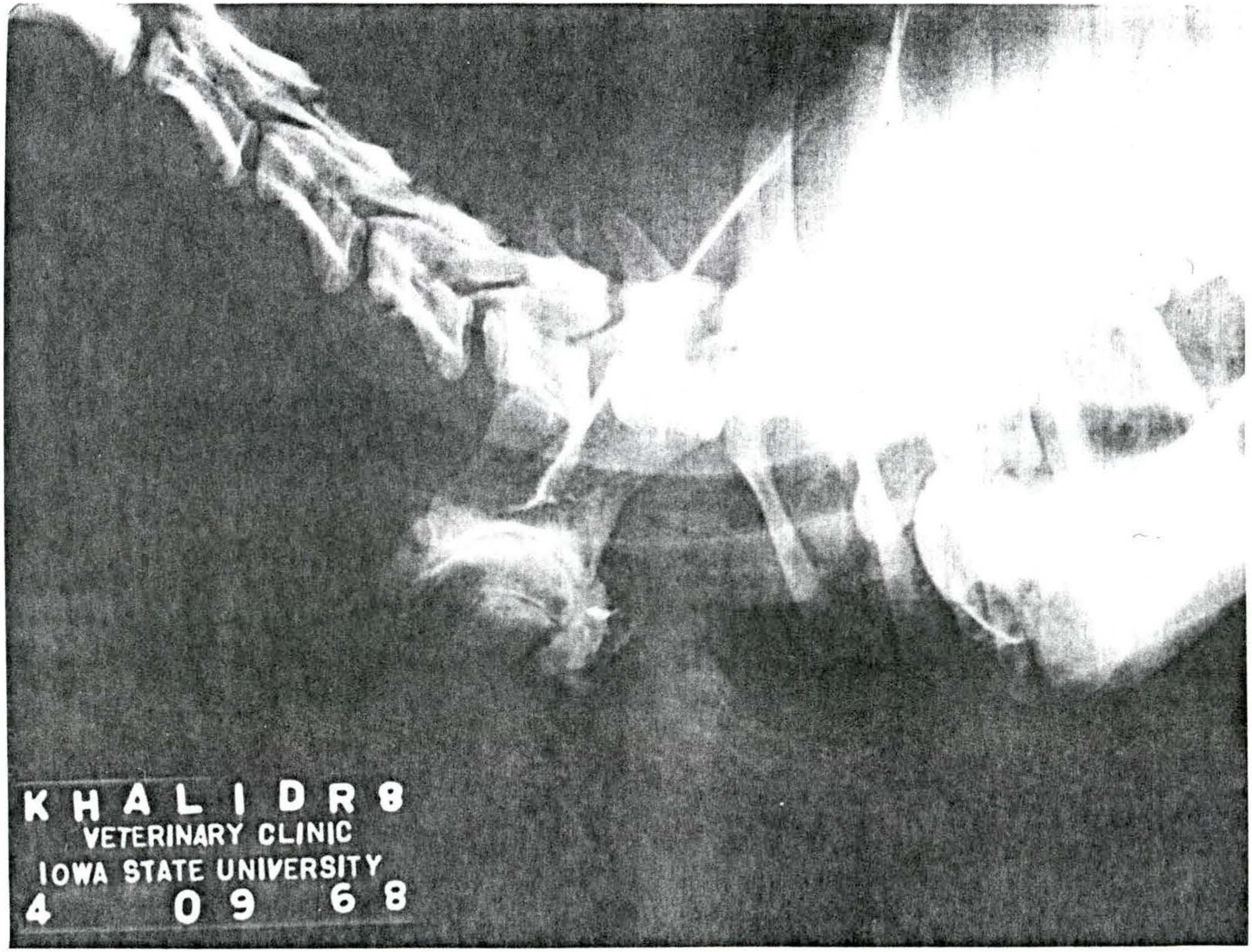
Figure 11. Arthrogram of the same joint taken 30 minutes after injection of Hypaque sodium into the joint capsule. The contrast medium is partially absorbed; a thin layer is seen covering the head of the humerus and the glenoid cavity. A thin line of dye is seen between the humeral head and the glenoid cavity. The articular cartilage of both the humerus and the glenoid cavity is also outlined by the dye.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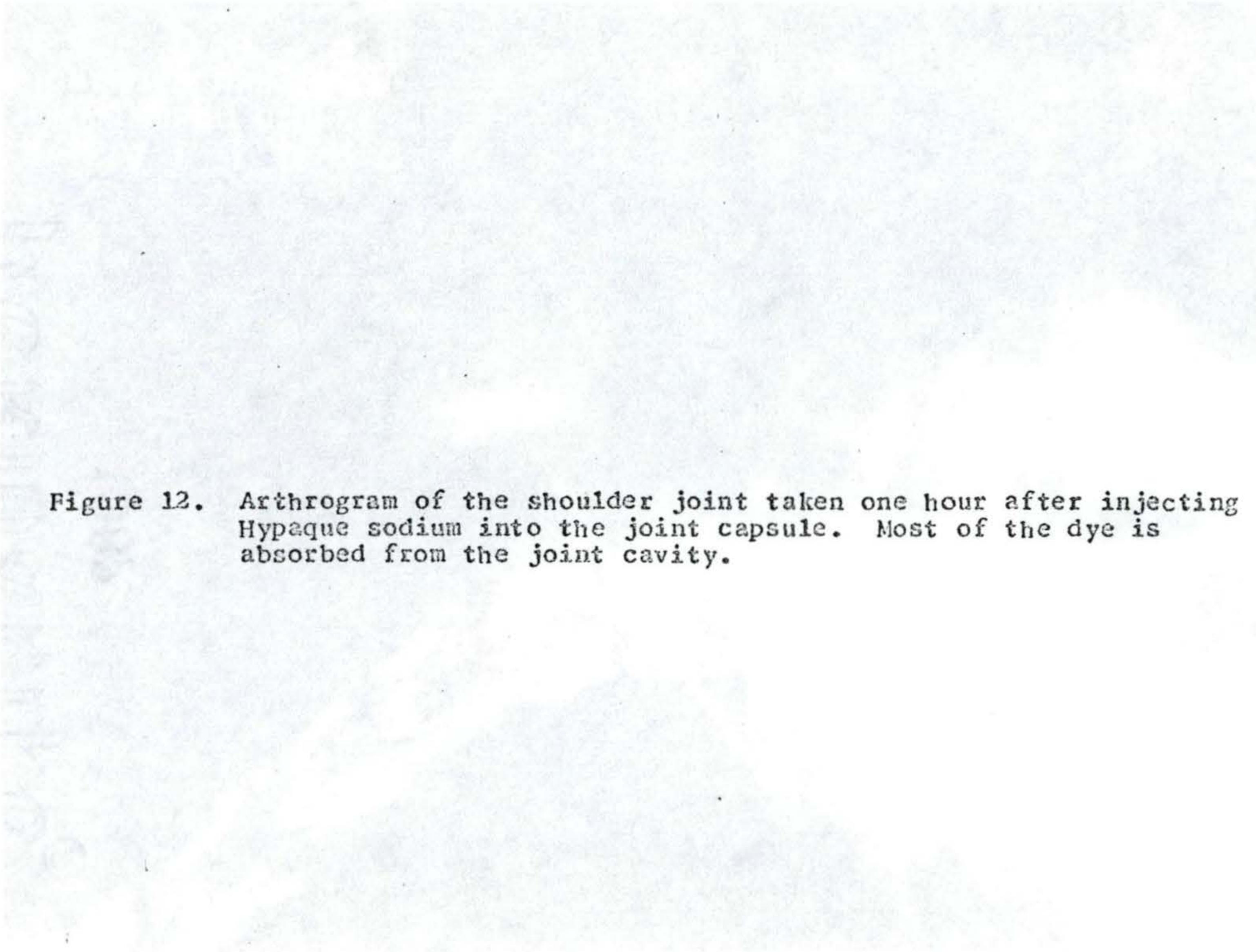

Figure 12. Arthrogram of the shoulder joint taken one hour after injecting Hypaque sodium into the joint capsule. Most of the dye is absorbed from the joint cavity.


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Figure 13. Arthrogram taken 90 minutes after introducing Hypaque sodium into the capsule of the shoulder joint. Traces of the contrast medium can be seen in the space between the head of the humerus and the glenoid cavity.

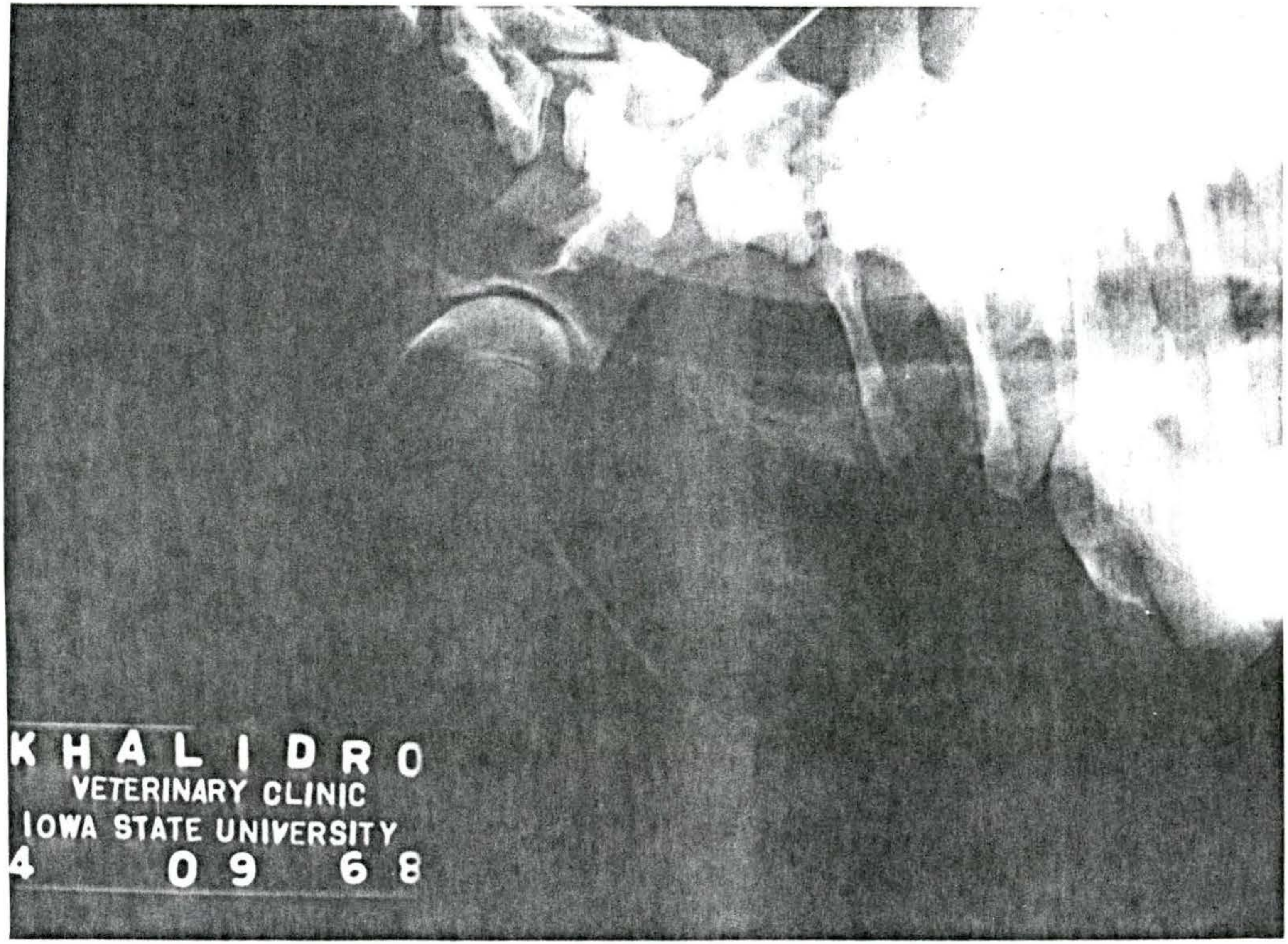
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Figure 14. Arthrogram taken two hours after injecting Hypaque sodium into the capsule of the shoulder joint. Note the dye is completely absorbed from the joint capsule and the joint appears normal.

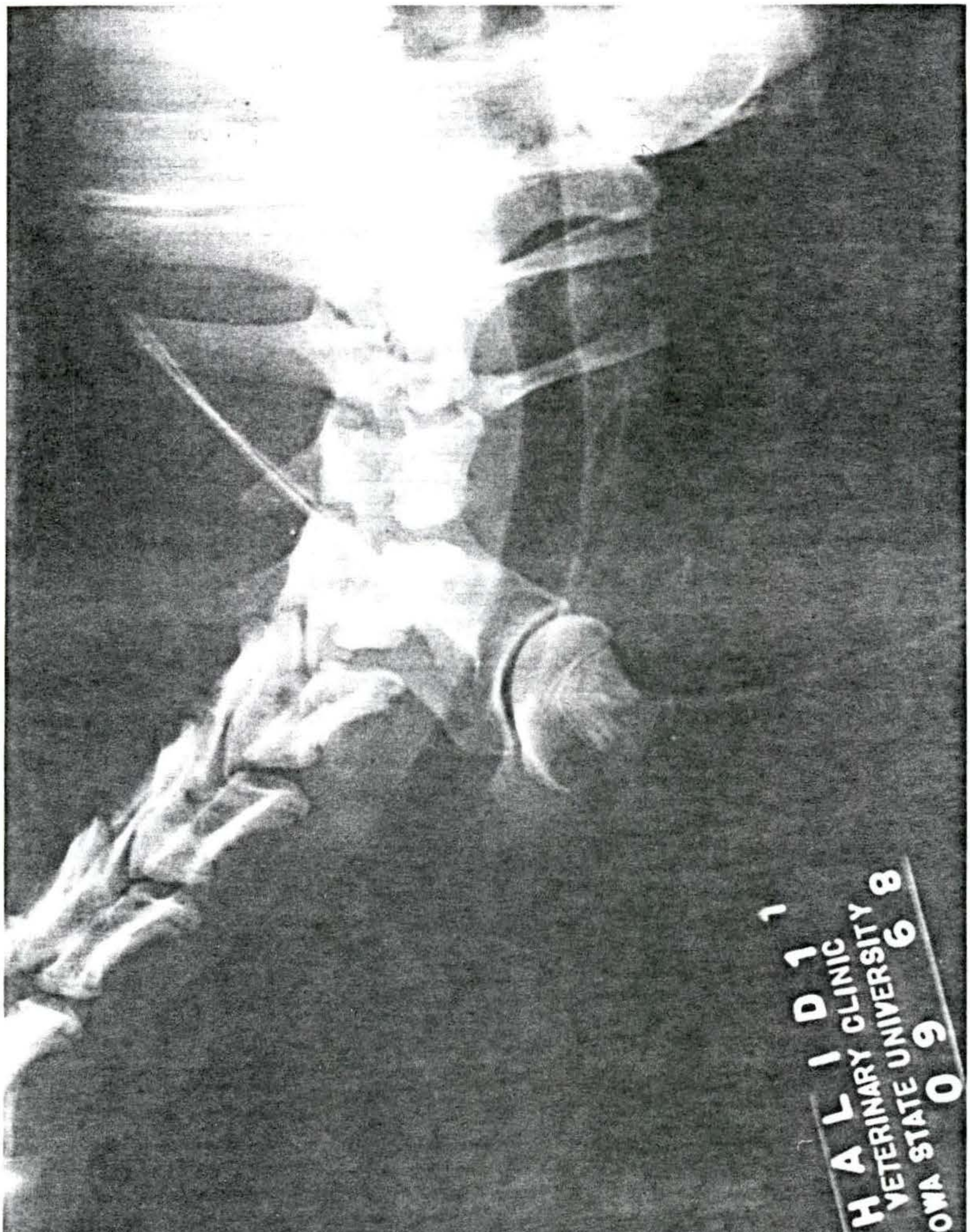
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Figure 15. Arthrogram of the same shoulder joint taken 24 hours after injecting Hypaque sodium into the joint capsule. Note the normal appearance of the joint.

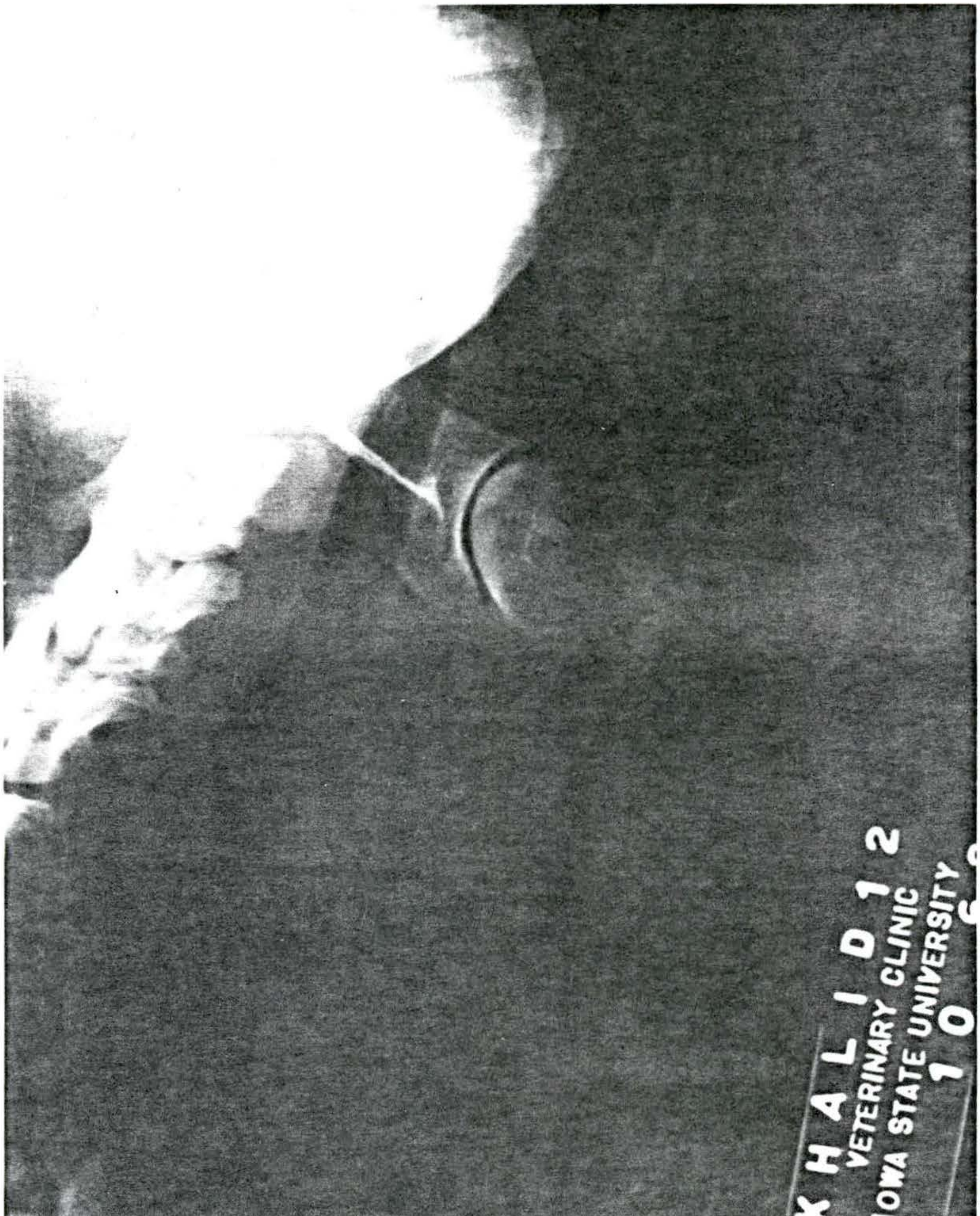
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Figure 16. Arthrogram of the normal elbow joint. Lateral view taken prior to the injection of double contrast medium.

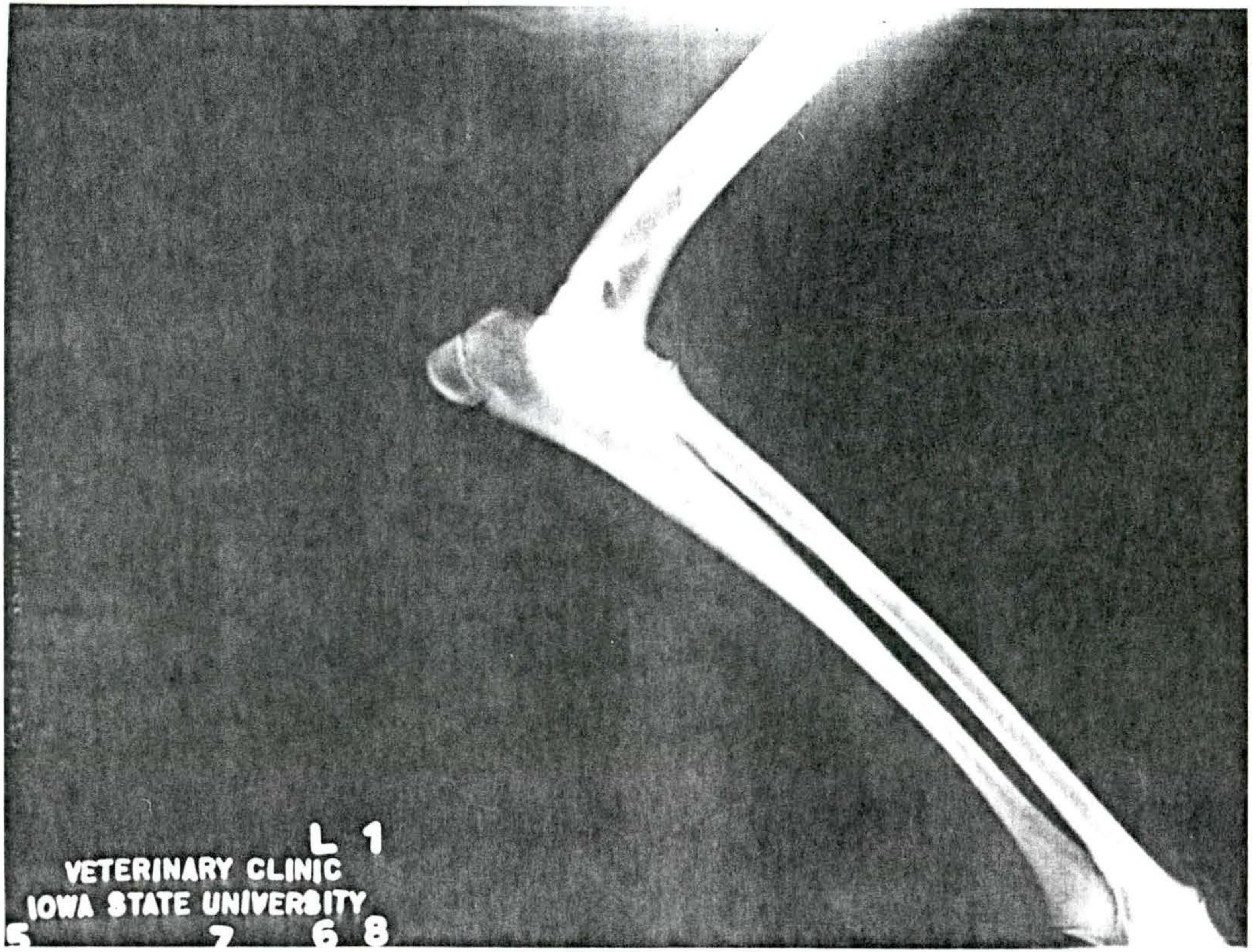
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Figure 17. Arthrogram of the normal elbow joint. Lateral view taken shortly after injection of 5 cc of 50% sodium diatrizoate (Hypaque sodium) and 15 cc of air into the joint capsule. Air is seen distending the joint capsule and the dye is evenly distributed in the joint capsule. On the anterior aspect the capsule is seen to be attached proximal to the trochlear foramen; on the posterior aspect the capsule is seen attached distal to the supratrochlear foramen. Part of the joint capsule is seen inserted between the radial notch of the ulna and the articular circumference of the radius. Caudally the capsule is observed to be distended upwards beneath the tendon of the triceps brachii.

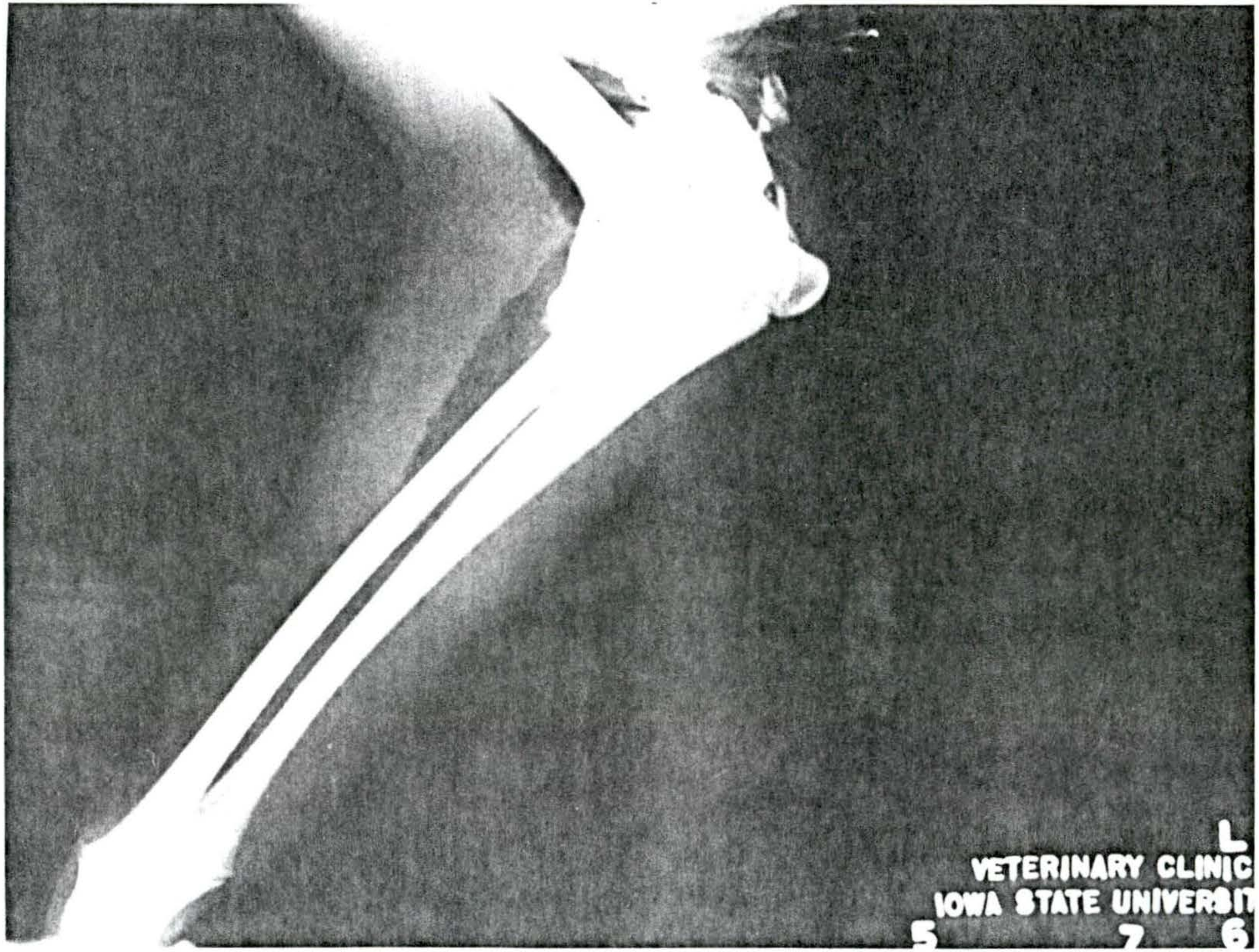
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Figure 18. Arthrogram of the same joint taken 30 minutes after the injection of the double contrast media into the elbow joint. Note the positive contrast medium is partially absorbed. The articular surfaces of the semilunar notch, radius and lateral condyle of the humerus are outlined by a thin layer of the positive contrast medium. The articular cartilage is also outlined by the contrast medium.

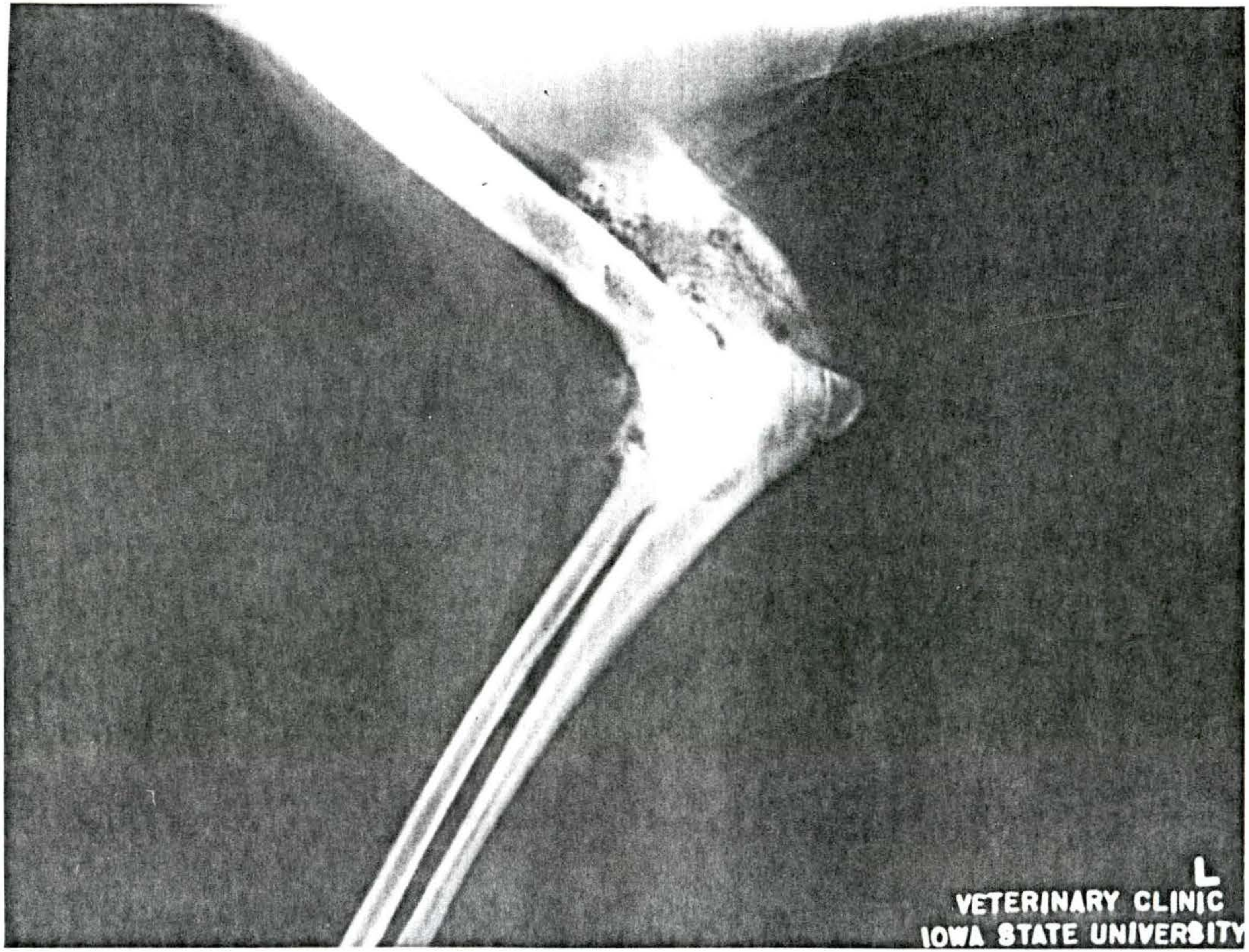
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Figure 19. Arthrogram of the elbow joint taken one hour after injecting the double contrast media into the joint capsule. Note that the positive contrast medium is partially absorbed from the joint cavity. The articular cartilage of the lateral condyle of the humerus and the head of the radius are well outlined by the positive contrast medium while the negative contrast medium (air) reveals the extent of both layers of the joint capsule on its anterior and posterior parts.

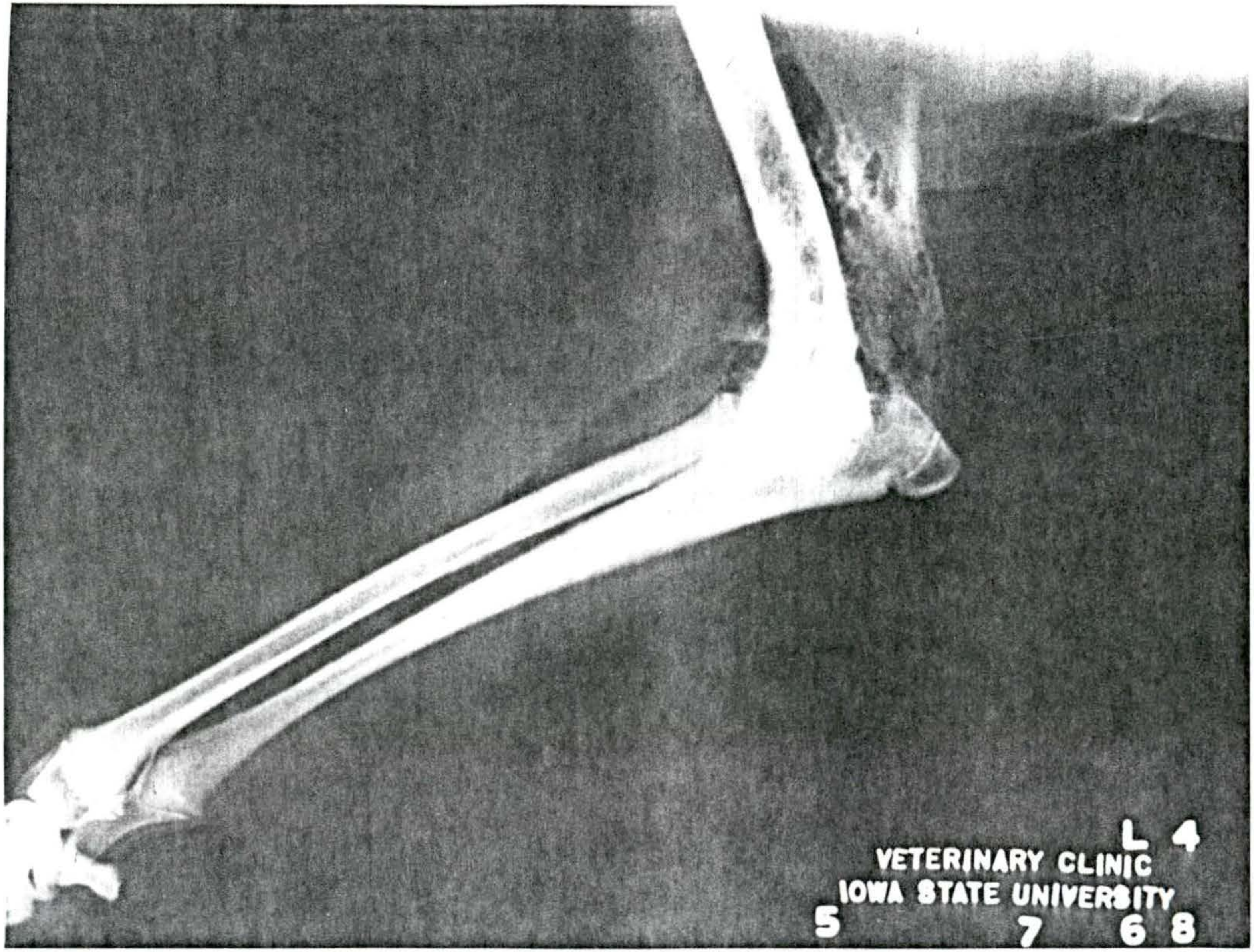
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Figure 20. Arthrogram of the elbow joint taken 90 minutes after injecting the double contrast media into the joint cavity. Note most of the positive contrast medium is absorbed from the joint cavity. Traces can be seen in the anterior part of the joint capsule. Positive contrast medium is also seen covering the articular cartilage of the radius, lateral condyle of the humerus and the semilunar notch of the ulna. Air is still seen clearly within the joint capsule.

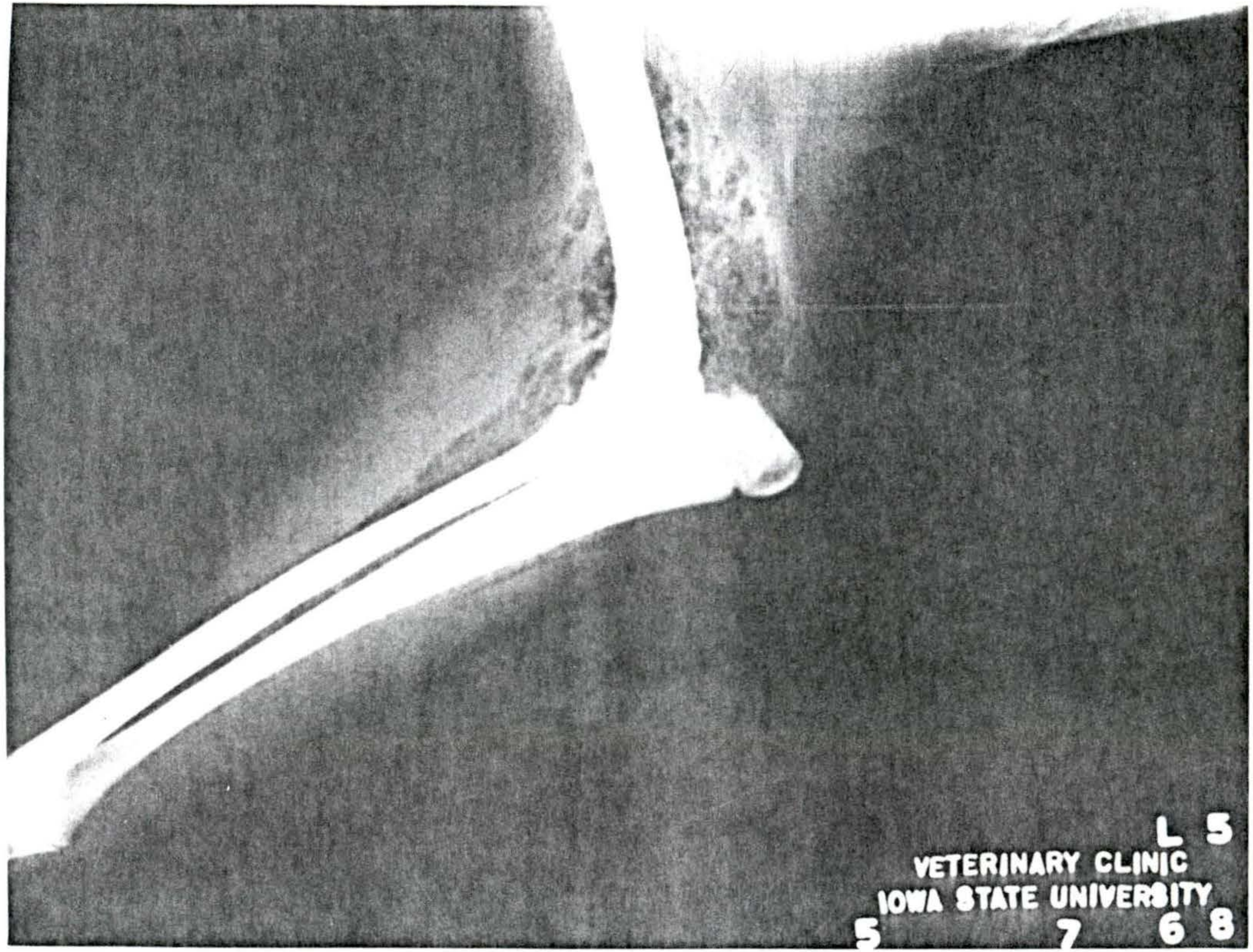
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Figure 21. Arthrogram taken two hours after introducing the double contrast media into the elbow joint cavity. Observe the complete absorption of the positive contrast medium (Hypaque sodium).

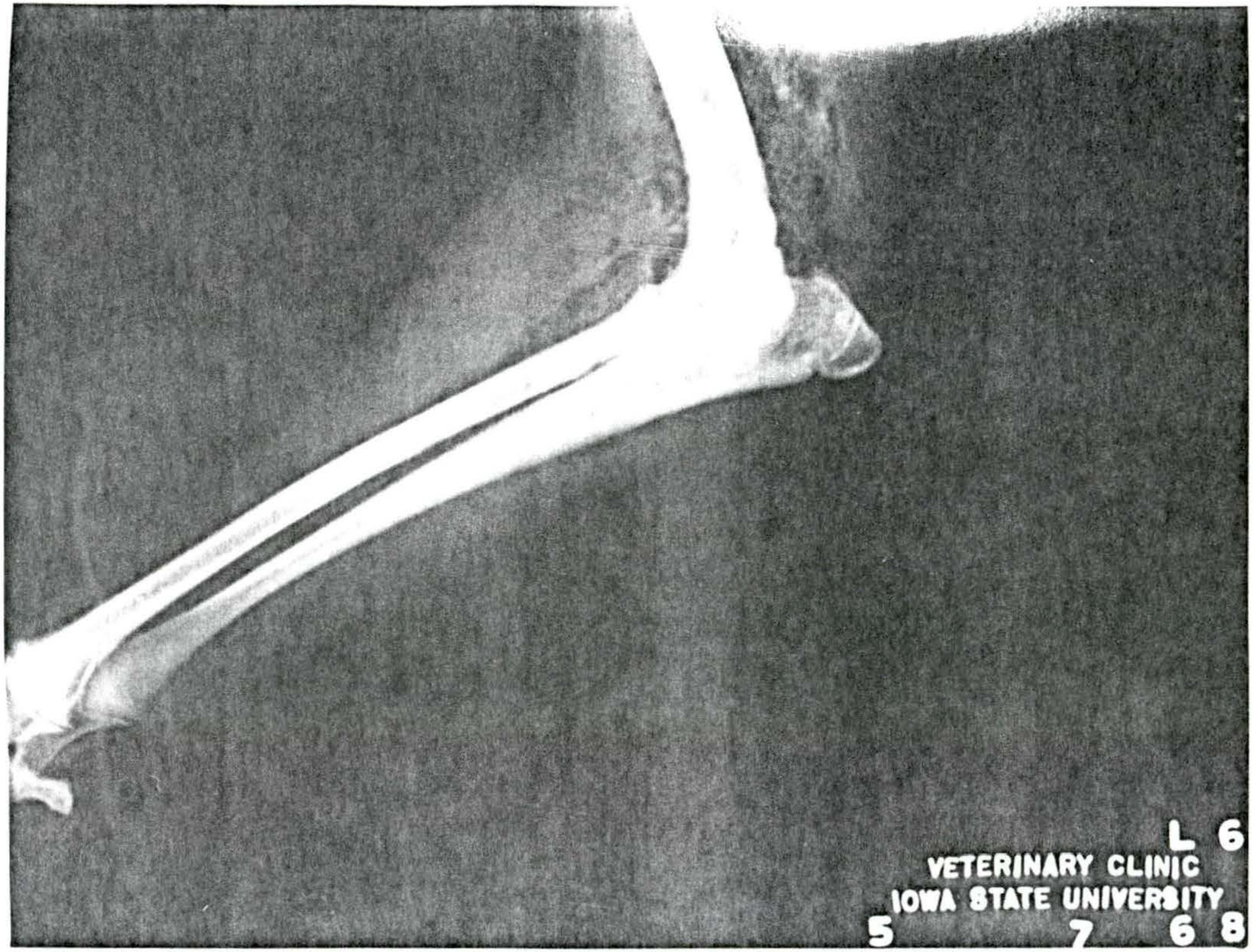
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Figure 22. Arthrogram taken 24 hours after the injection of the double contrast medium into the joint capsule

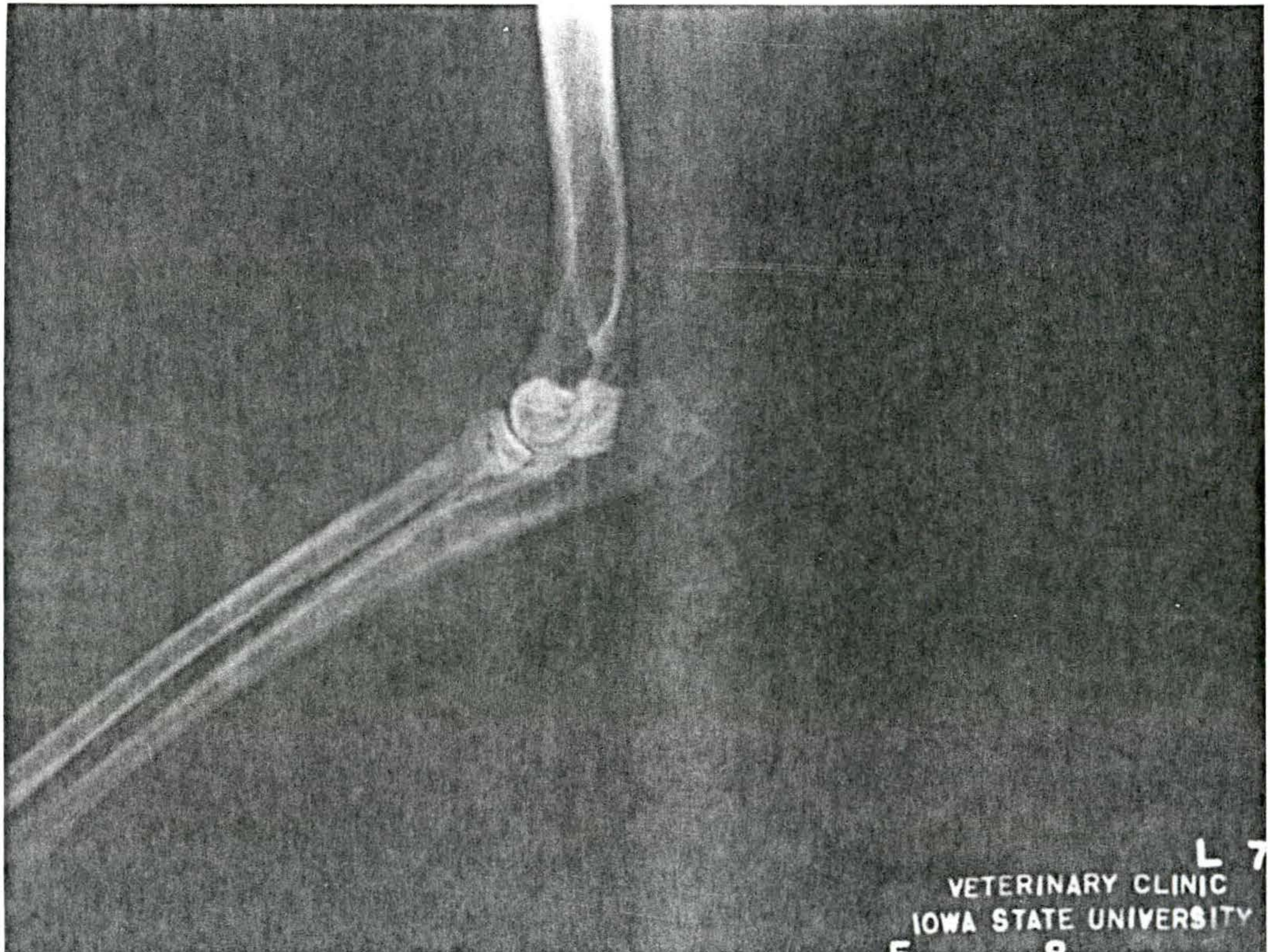
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Figure 23. Arthrogram taken two days after introducing the double contrast media into the joint capsule of the elbow joint. Air is completely absorbed from the joint capsule, but some air can still be seen in the surrounding soft tissue.

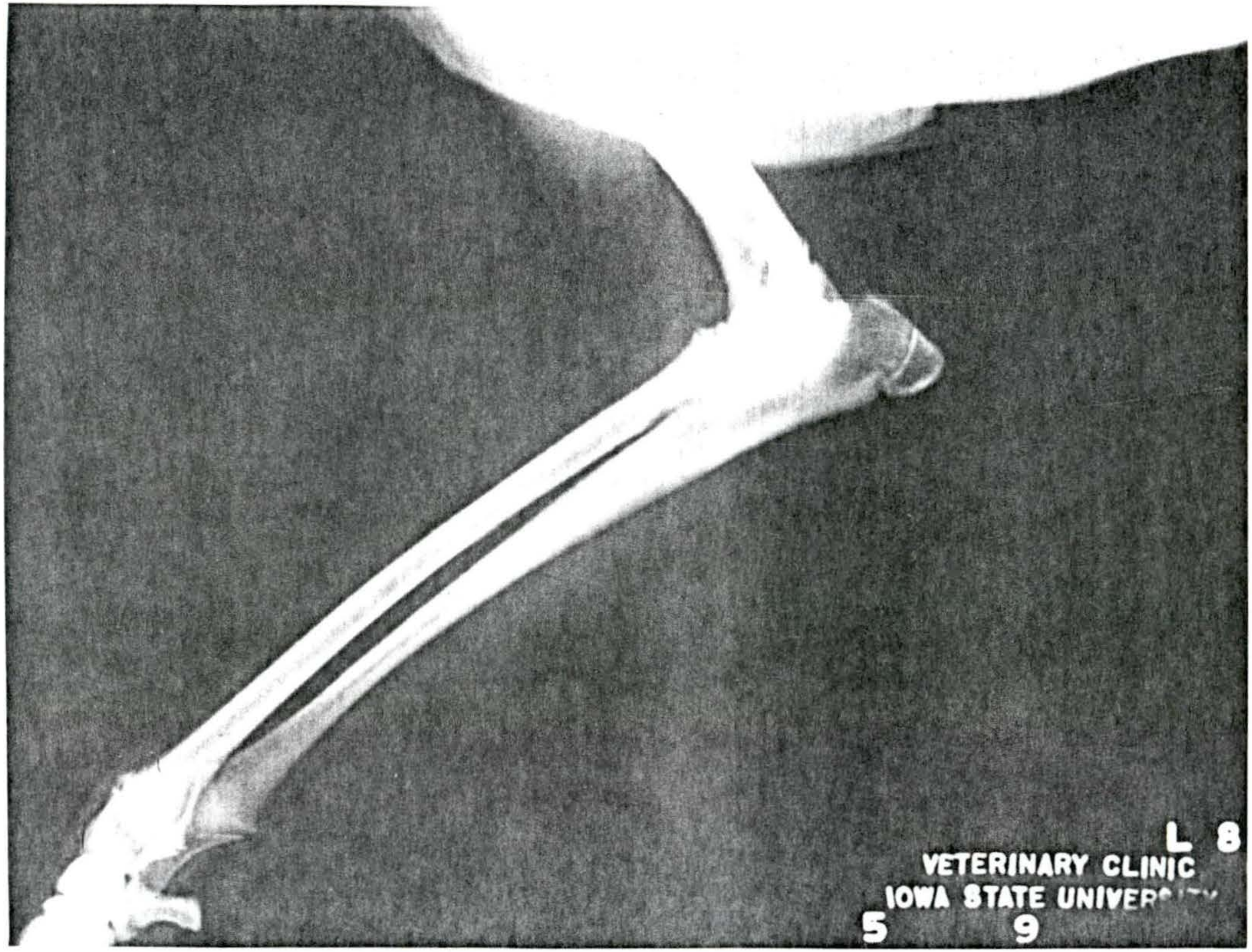
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Figure 24. Arthrogram taken three days after the injection of double contrast media into the joint capsule of the elbow joint. Complete absorption of air has taken place from the joint capsule and surrounding soft tissue.

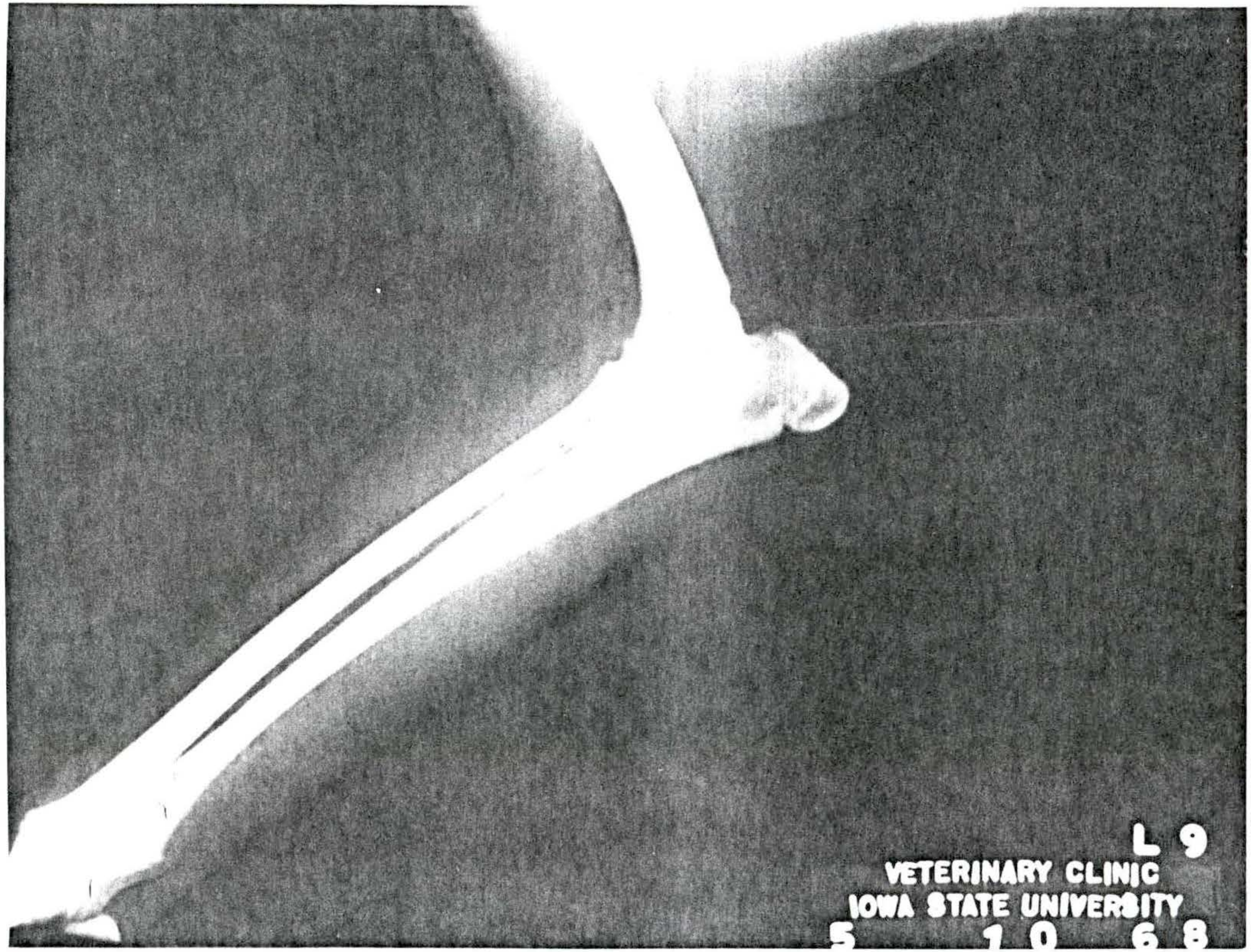
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Figure 25. Arthrogram of a normal carpal joint. Dorso-ventral view taken prior to injection with sodium iodide.

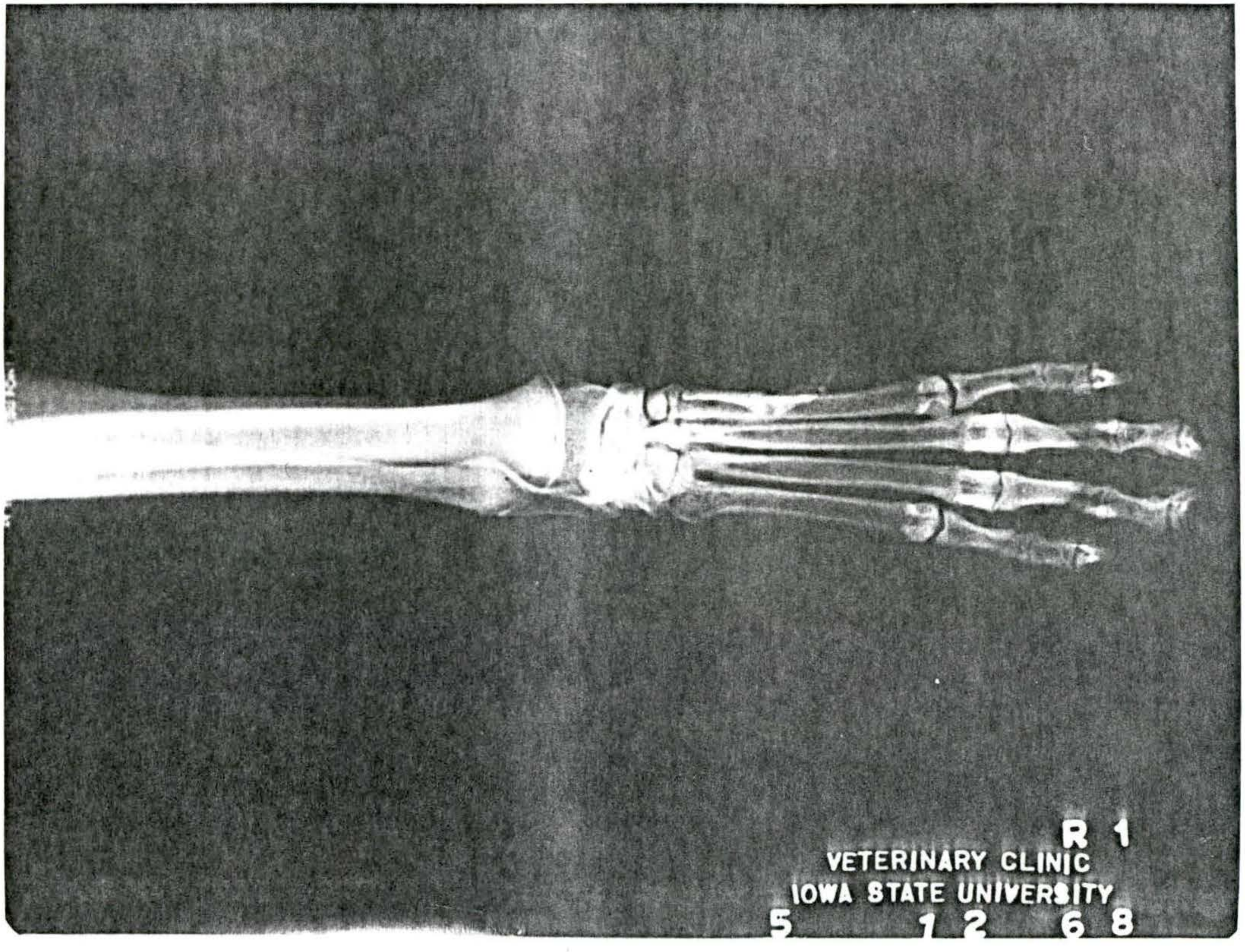
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Figure 26. Arthrogram of the carpal joint. Dorso-ventral view taken shortly after injecting 1 cc of 20% solution of sodium iodide into radio-carpal joint capsule and 1 cc into carpometacarpal joint capsule.

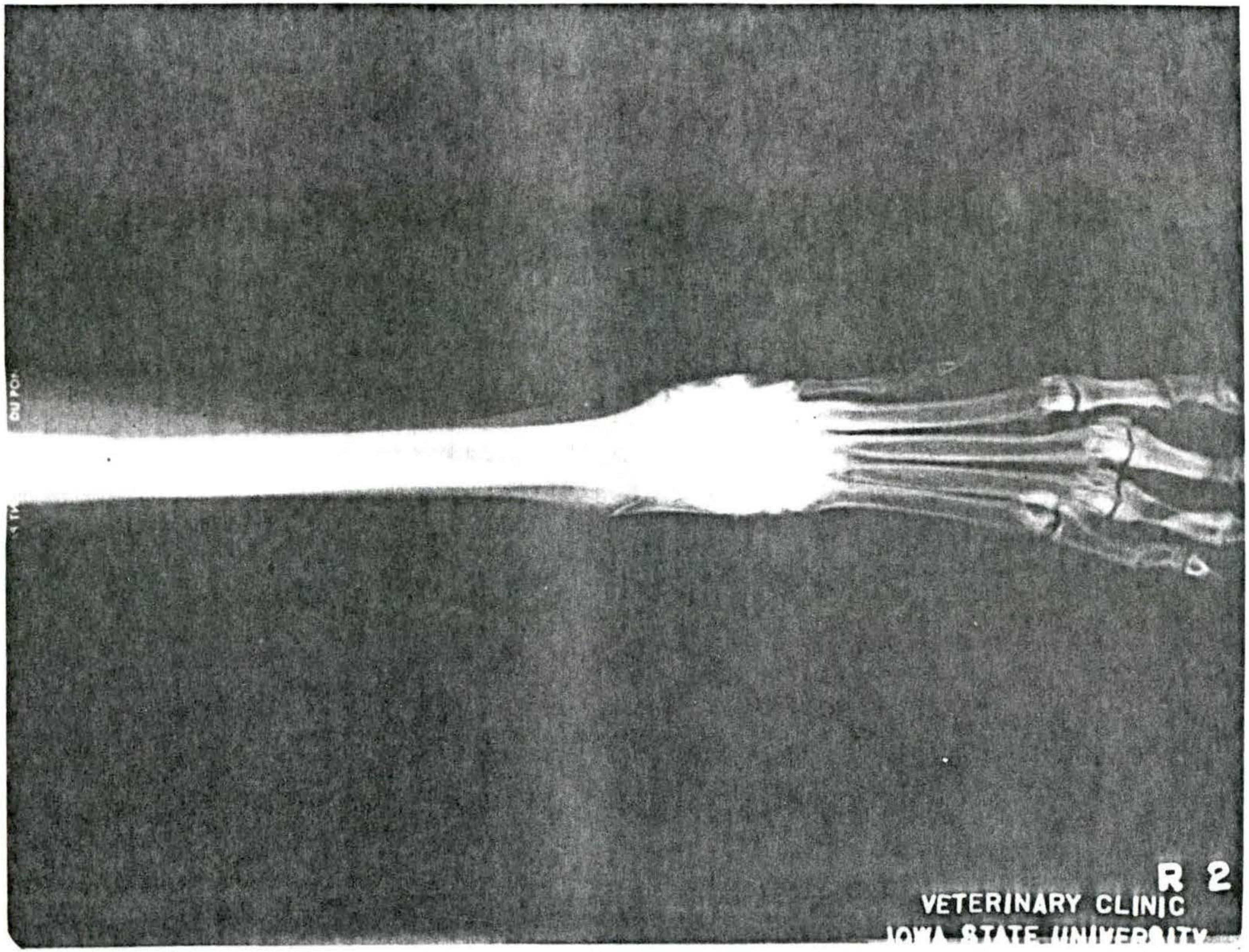
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Figure 27. Arthrogram of the carpal joint. Mediolateral view. Note some of the contrast medium inside the joint capsule and some that has leaked out of it occupying the space between the superficial and deep parts of the transverse palmar carpal ligament.

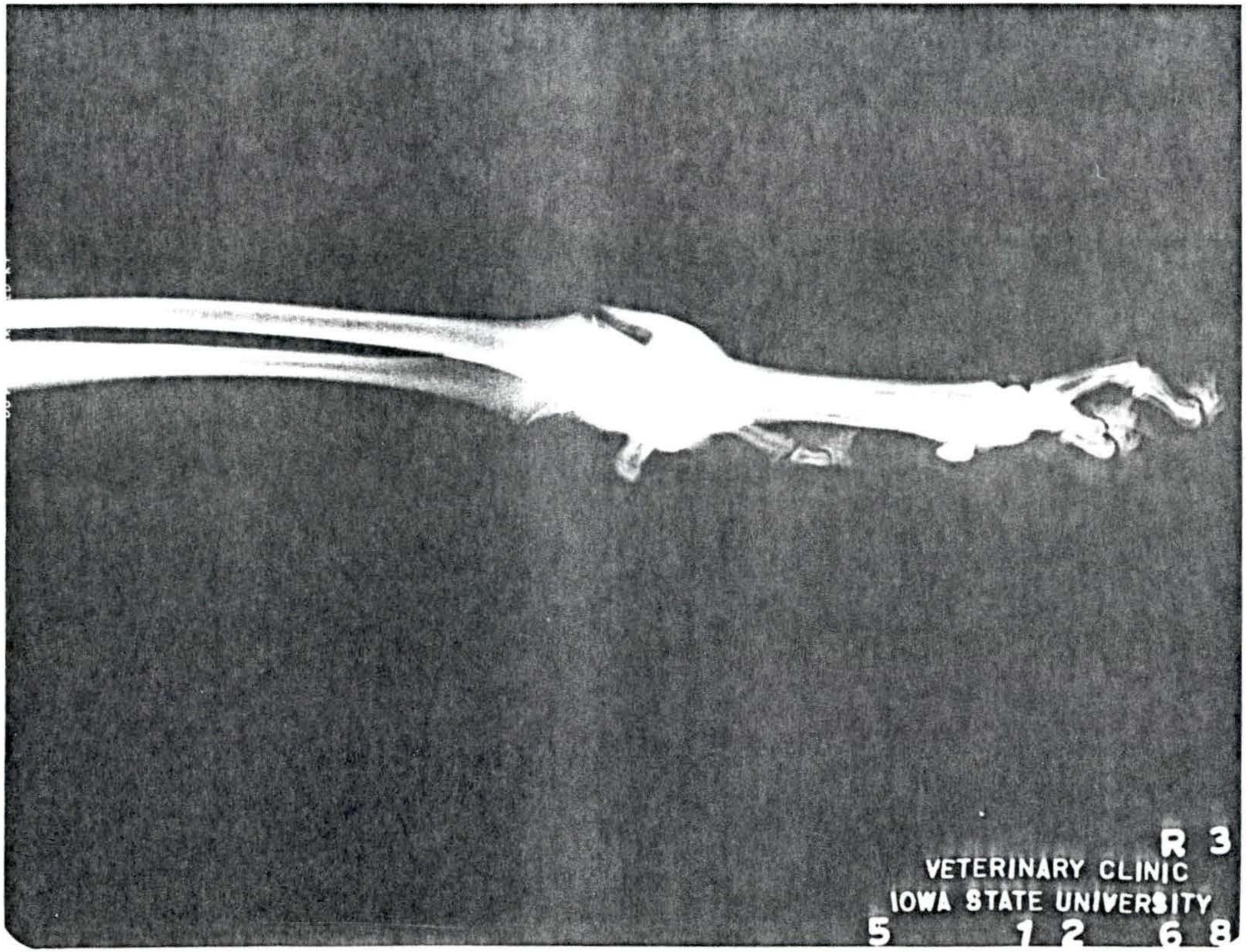
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Figure 28. Arthrogram of the carpal joint taken 30 minutes after injecting 20% sodium iodide into the joint capsules. Observe the swelling of the soft tissue due to the irritation of the sodium iodide which escaped from the joint capsules. The spaces between the distal articular surfaces of radius, ulna and proximal articular surfaces of radial carpal bone and ulnar carpal bone. Contrast medium can also be seen surrounding I, II, III and IV carpal bones.

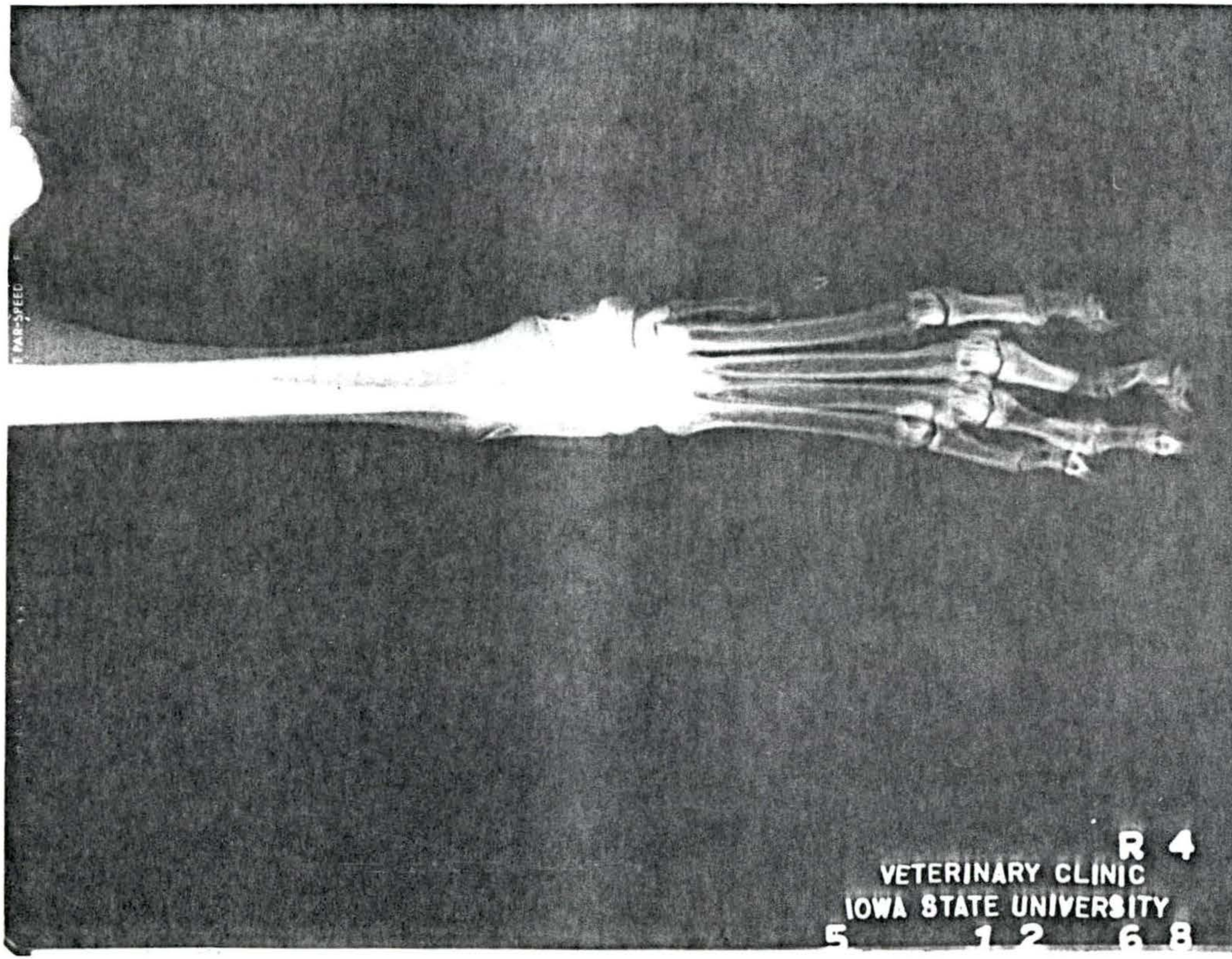
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Figure 29. Arthrogram taken one hour after injection of sodium iodide into the carpal joint capsules. Note the contrast medium is partially absorbed from the joint capsule. Some contrast medium can still be visualized between the articular surfaces of the bones within the joint cavity.

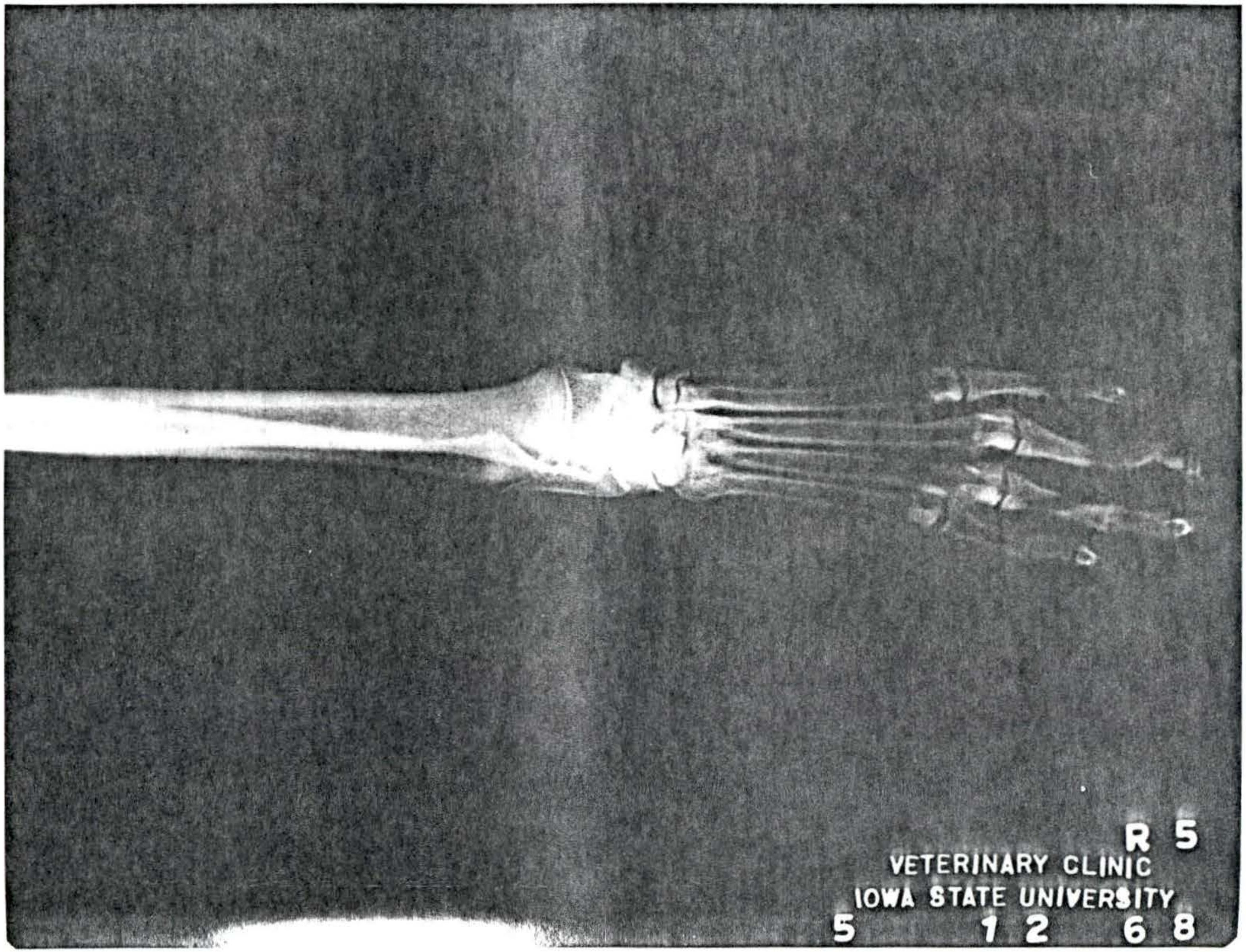
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Figure 30. Arthrogram taken 90 minutes after injection of sodium iodide into the carpal joint. Note traces of the contrast medium.

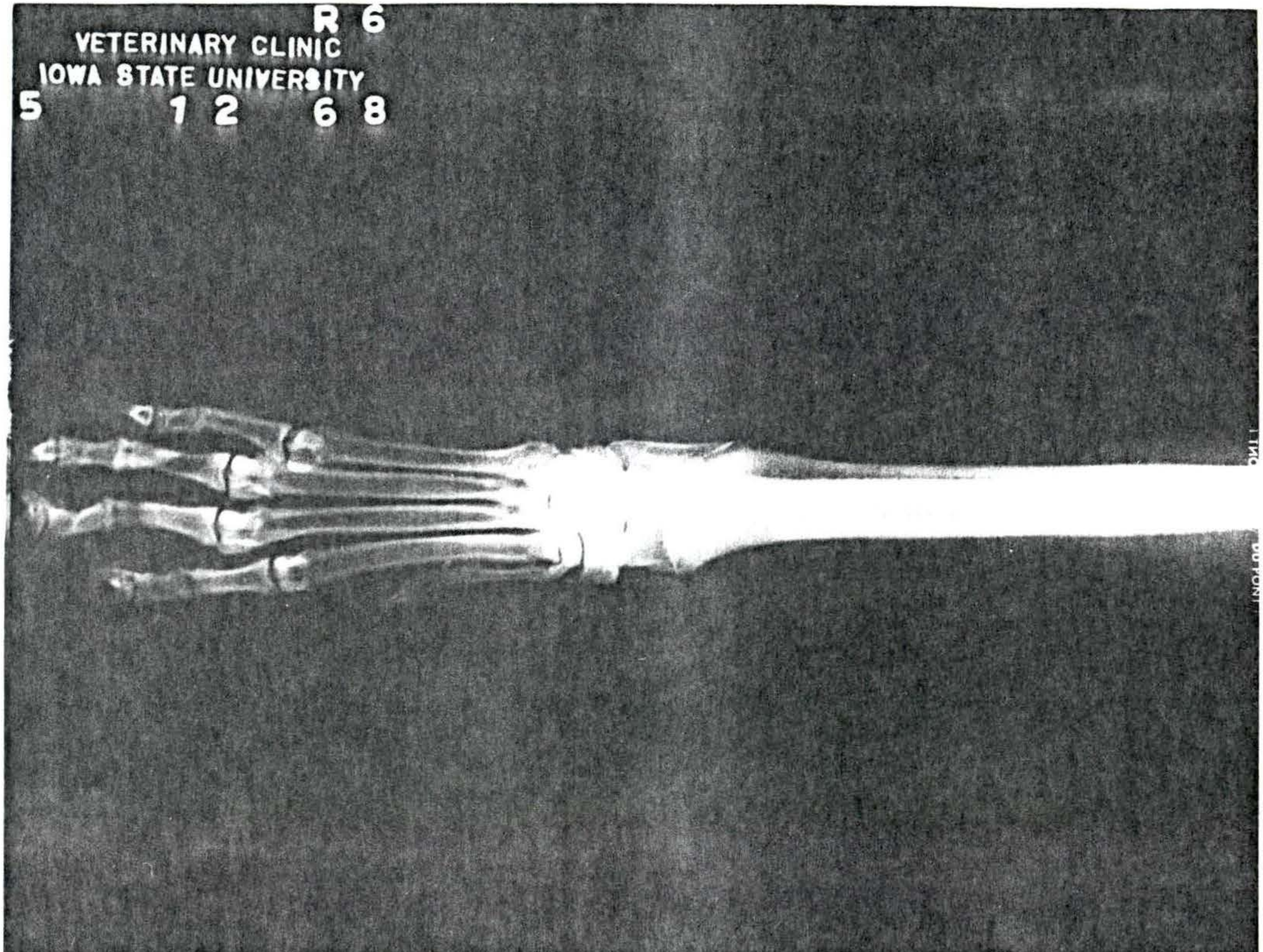
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Figure 31. Arthrogram taken two hours after injection of sodium iodide into the joint capsules. Observe the complete absorption of the contrast medium from the joint capsules.

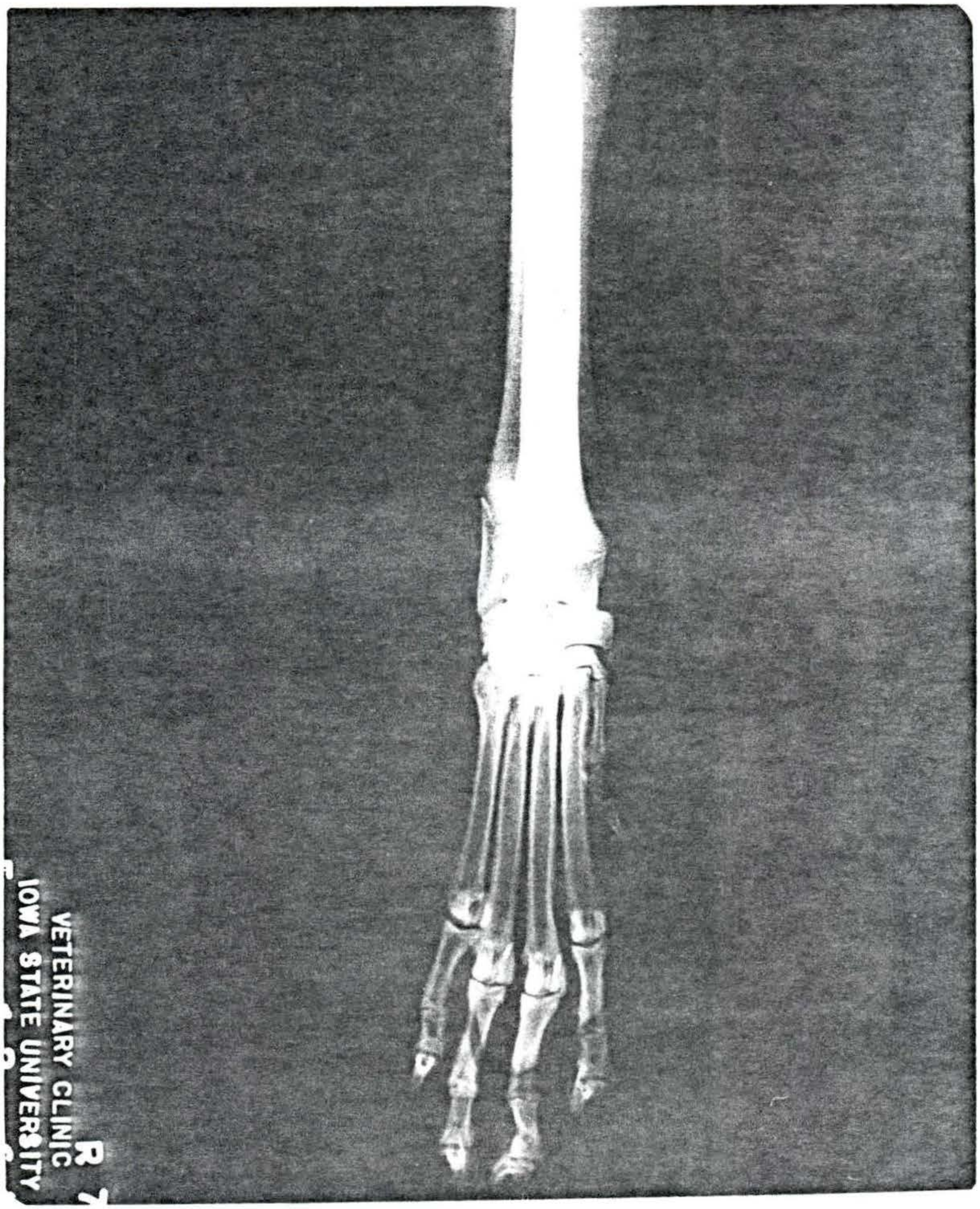
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Figure 32. Arthrogram taken one week after injection of 20% sodium iodide into the joint capsules of the carpal joint. Note the swelling of the soft tissue has disappeared and the joint appears to be normal.

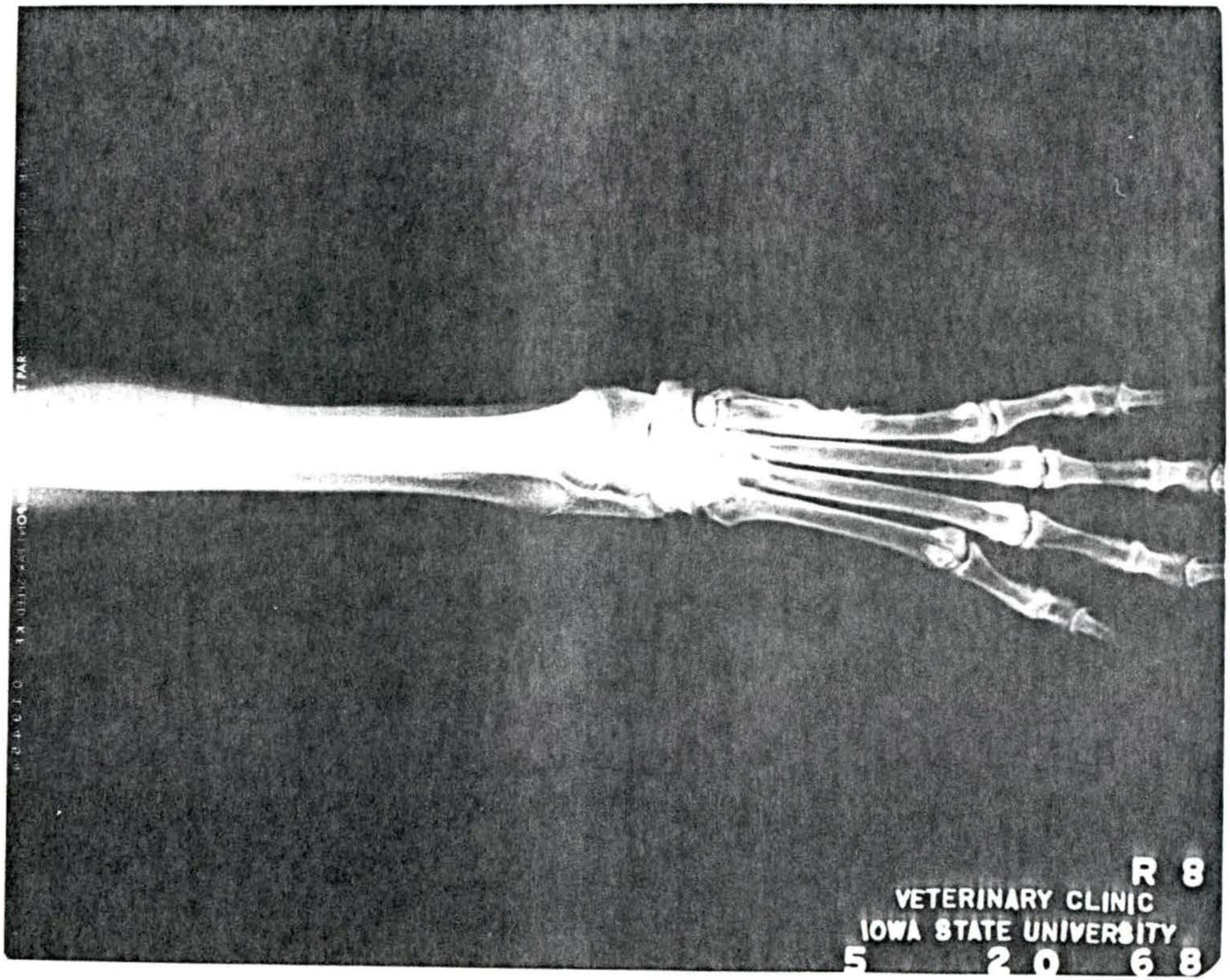
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Figure 33. Arthrogram of the normal hip joint. Ventro-dorsal view taken before injection with Skiodan (sodium iodomethanesulfanate: Winthrop Laboratories, New York, N. Y.).

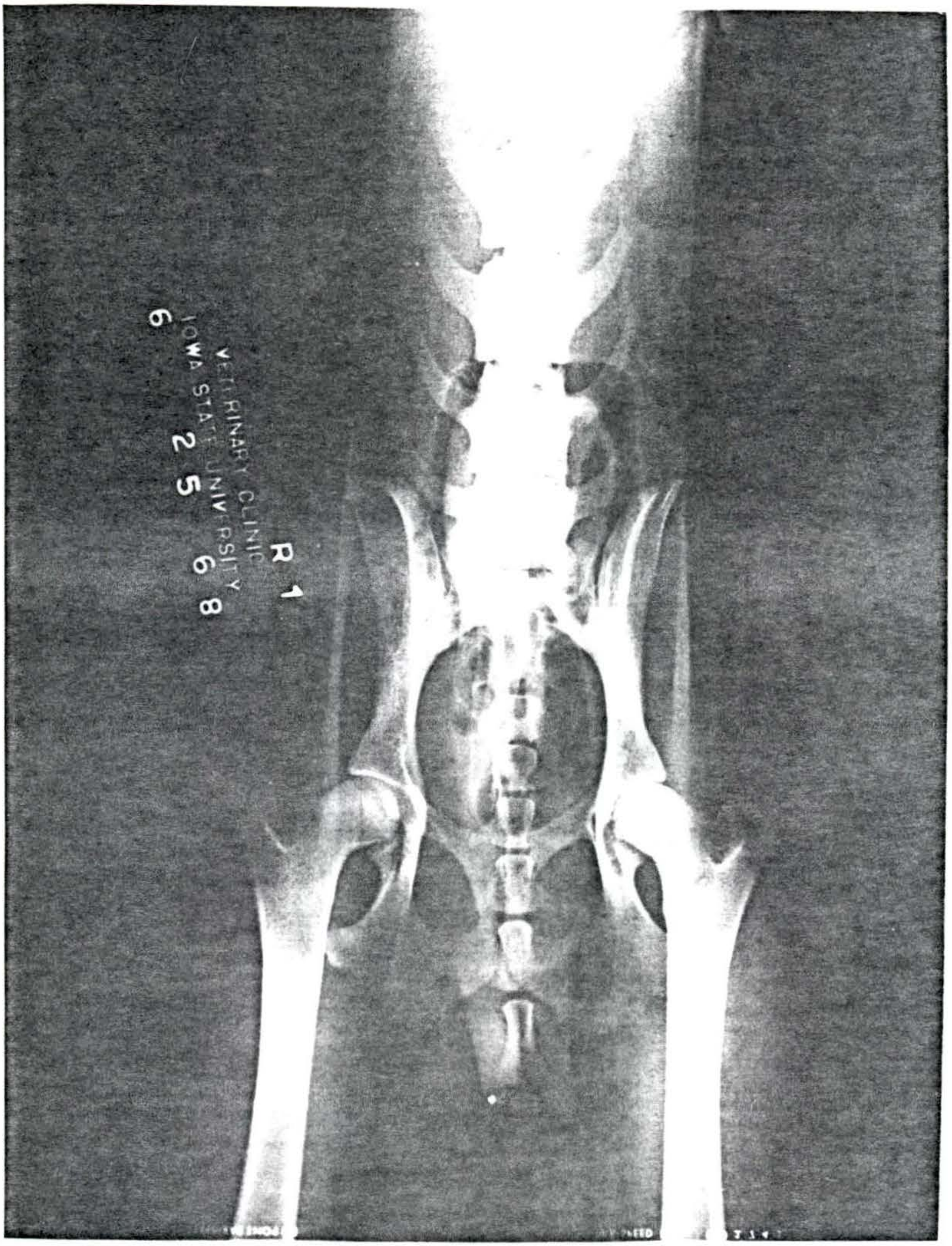
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Figure 34. Arthrogram of the normal hip joint. Ventro-dorsal view taken shortly after injecting the right joint capsule with 5 cc of Skiodan. Joint capsule is filled with the contrast medium. The capsule is seen attached to the acetabular edge proximally and to the neck of the femur distally.

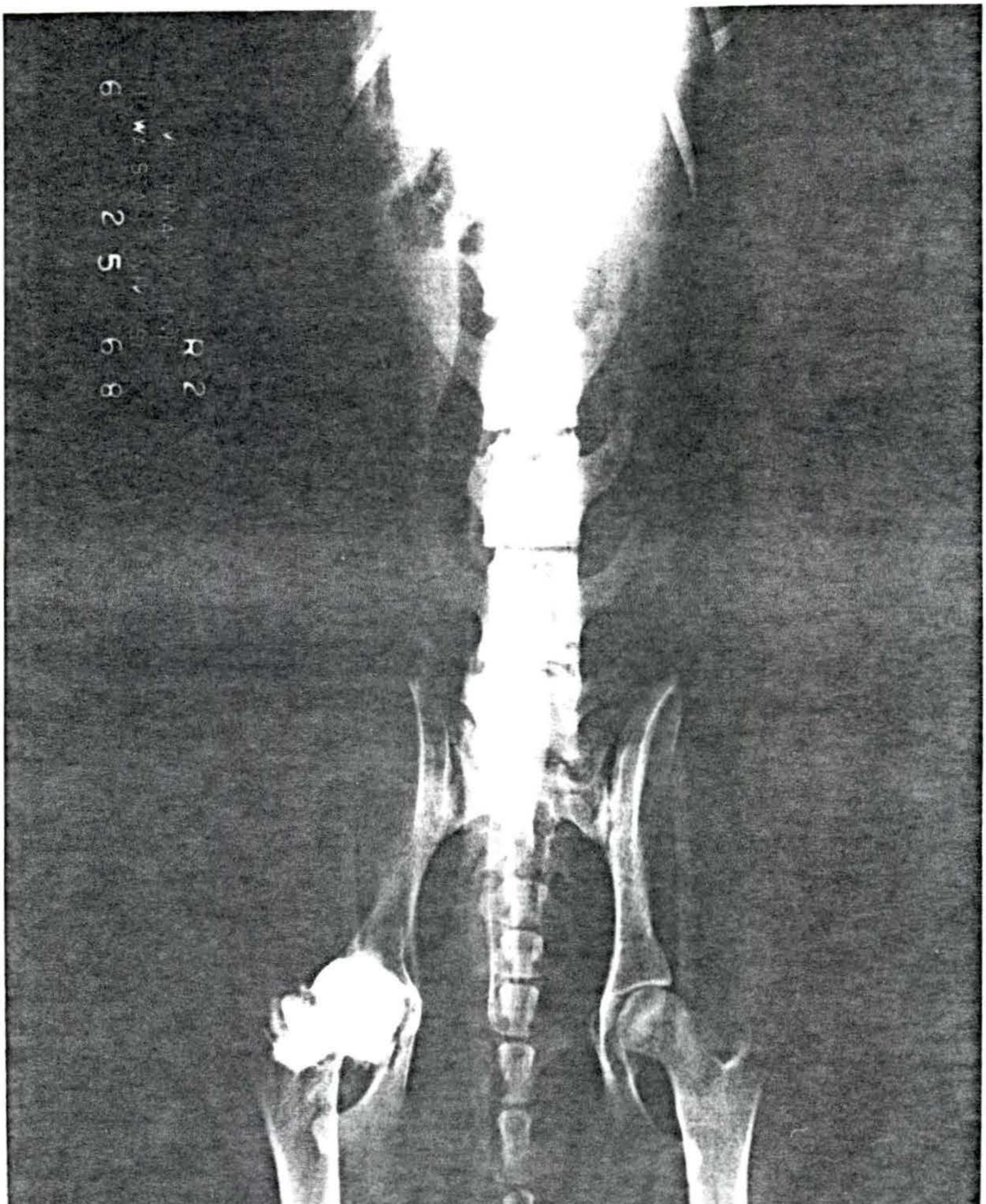

Figure 35. Arthrogram of the hip joint "frog position". This position demonstrated the contrast medium in the caudal part of the joint capsule, joint space and acetabular edge.

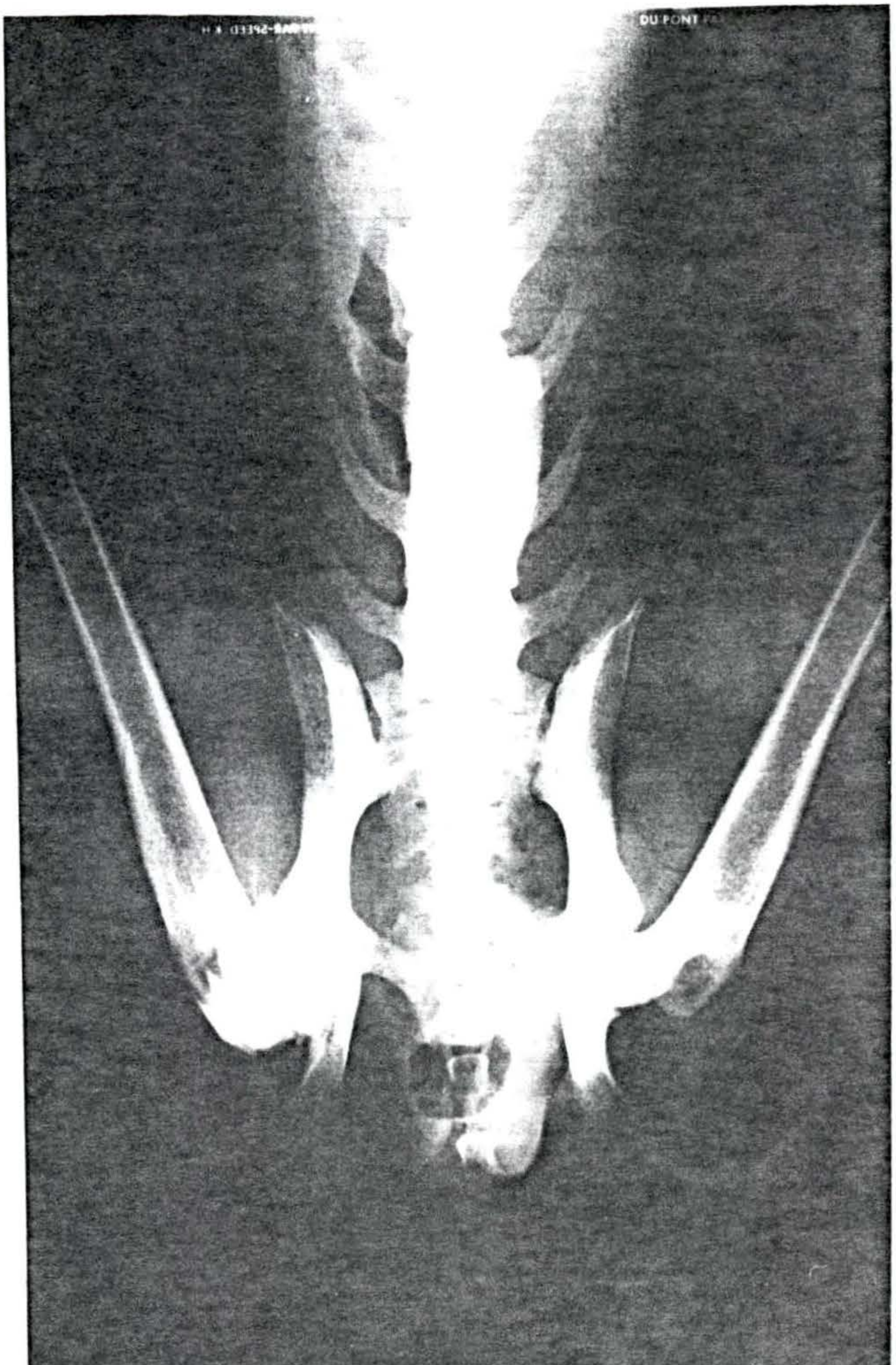
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Figure 36. Arthrogram taken 30 minutes after injection of Skiodan into the right joint capsule. Note the dye is partially absorbed. A thin line of the contrast medium is seen between the acetabulum and the femoral head. A thin layer of the contrast medium is also seen covering the head and the neck of the femur.

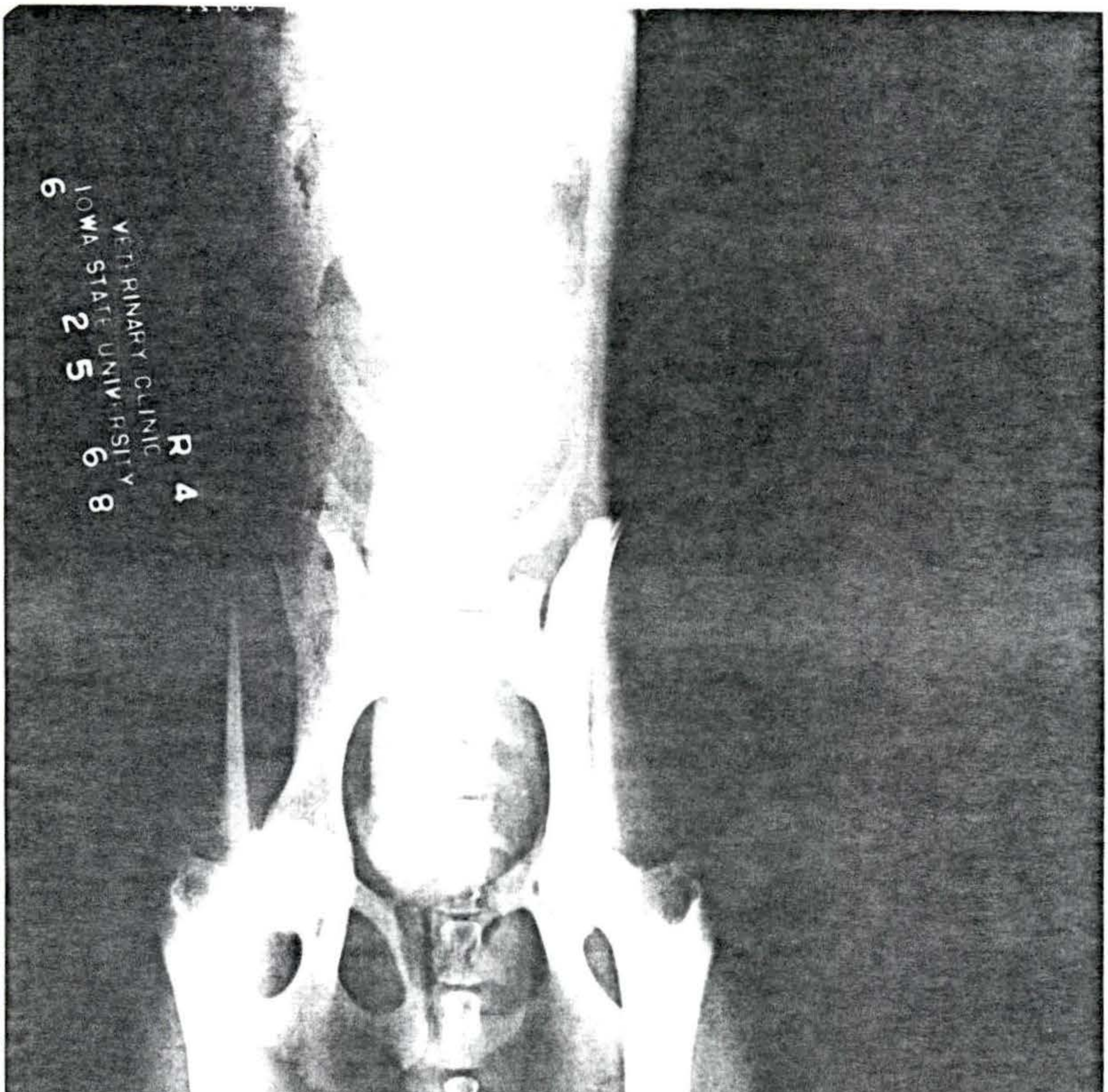
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Figure 37. Arthrogram taken one hour after injection of Skiodan into the right joint capsule of the hip. Note some contrast medium is still seen in the joint space, femoral head and neck. Contrast medium can also be seen accumulated in the urinary bladder.

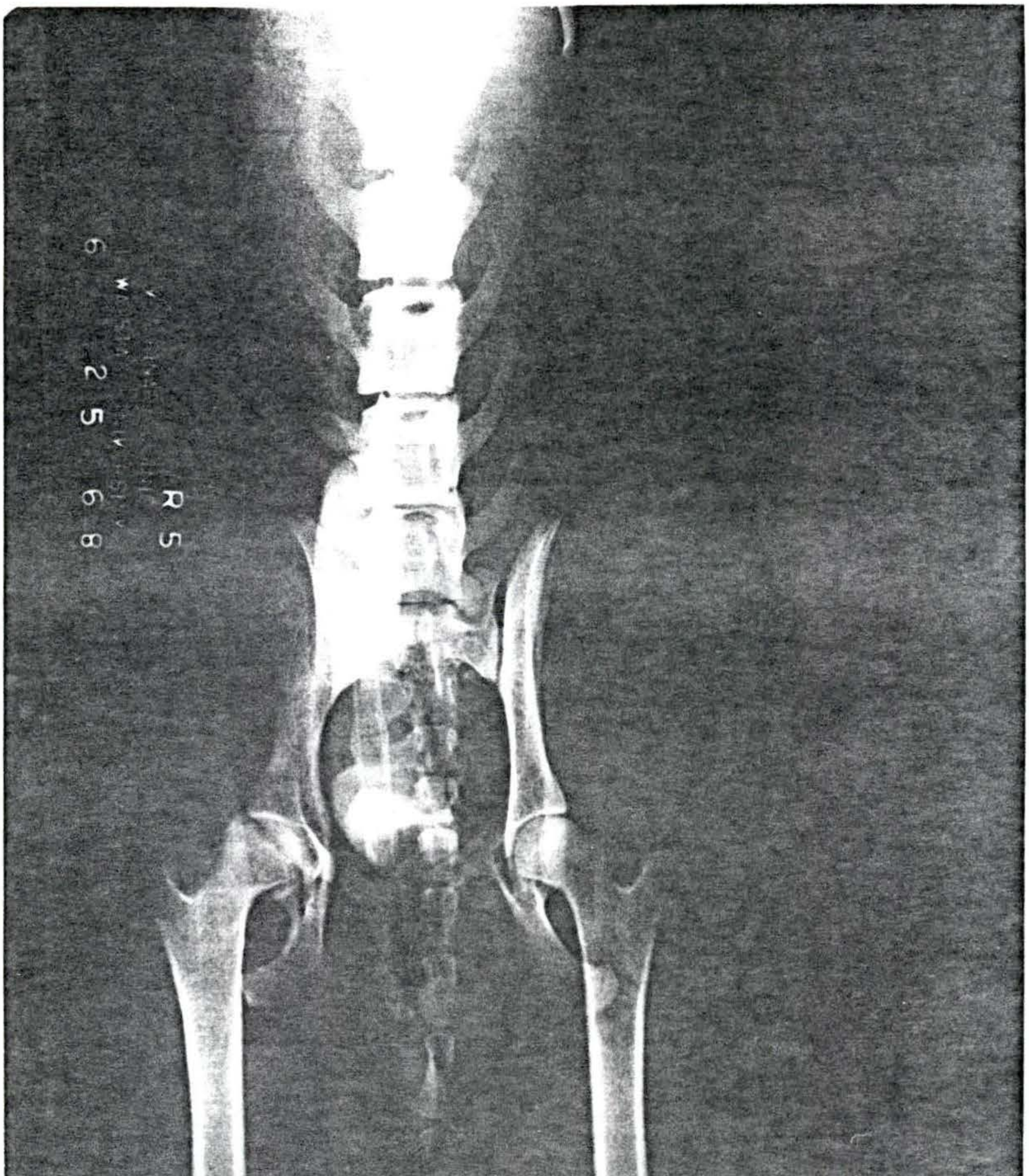


Figure 38. Arthrogram taken 90 minutes after injection of Skiodan into the joint capsule of the right hip. Note the amount of the contrast medium is increasing in the urinary bladder.

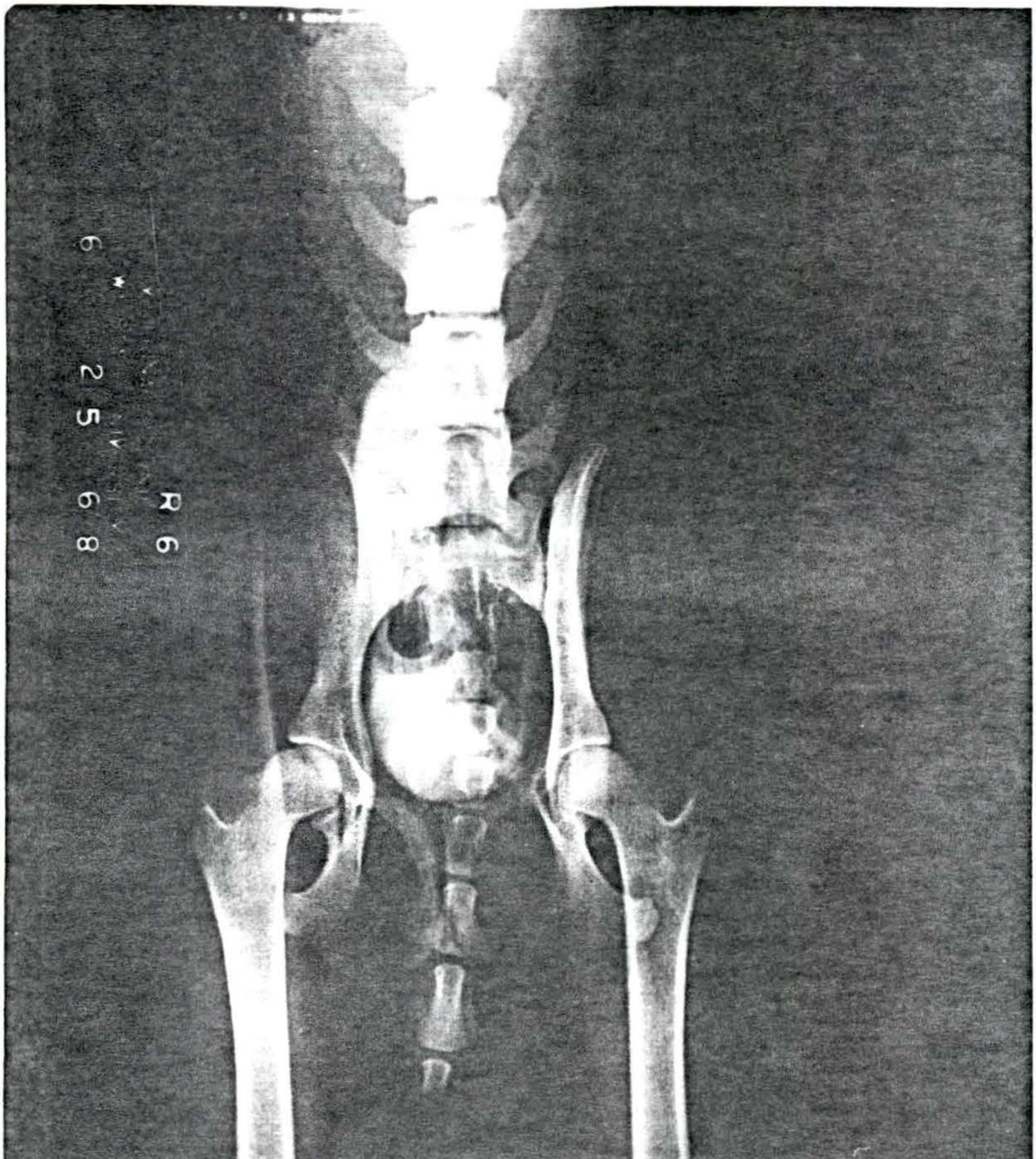


Figure 39. Arthrogram taken two hours after injection of Skiodan into the joint capsule of the right hip. Observe the complete absorption of the contrast medium from the joint capsule. The urinary bladder is seen to be filled with the contrast medium.

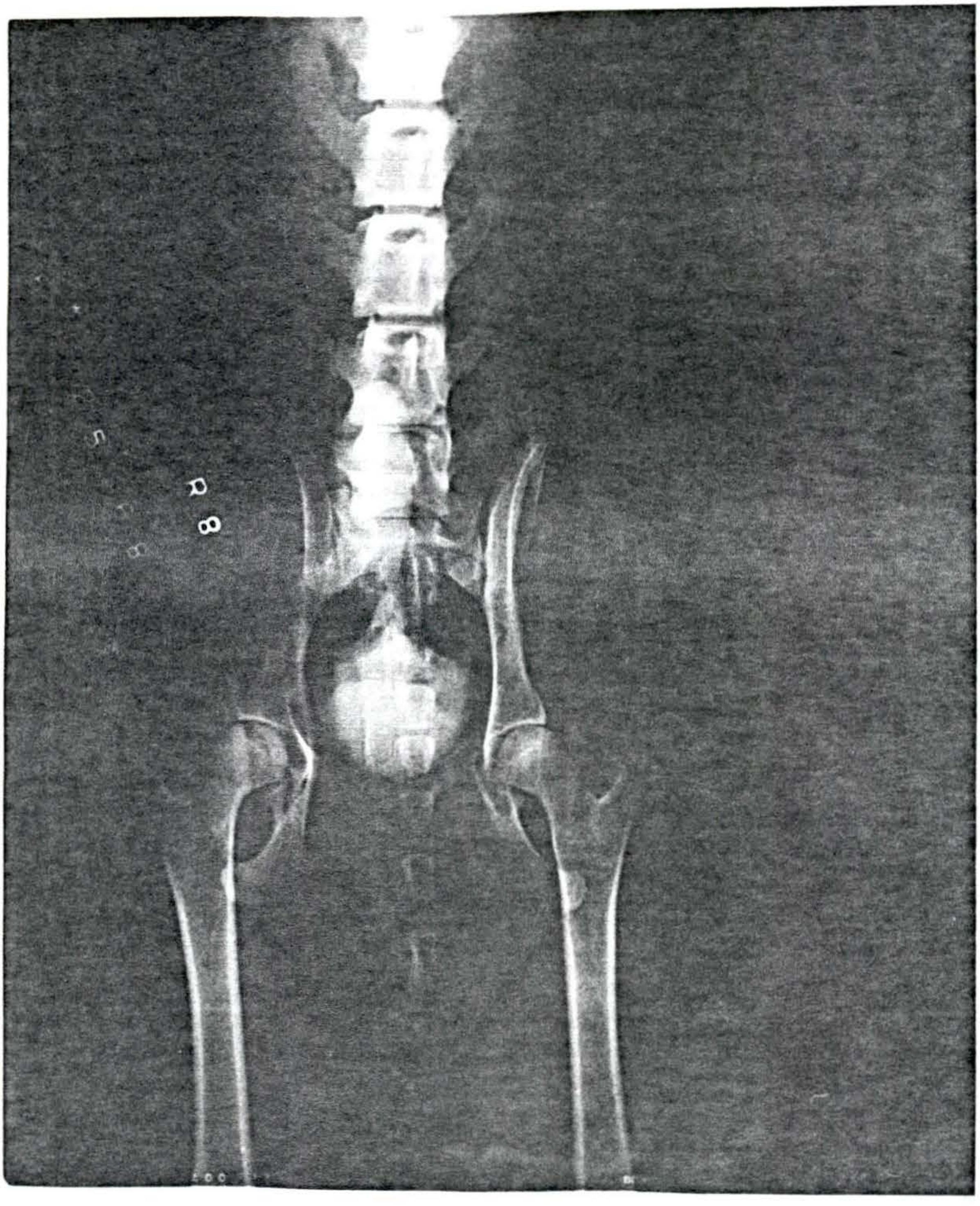
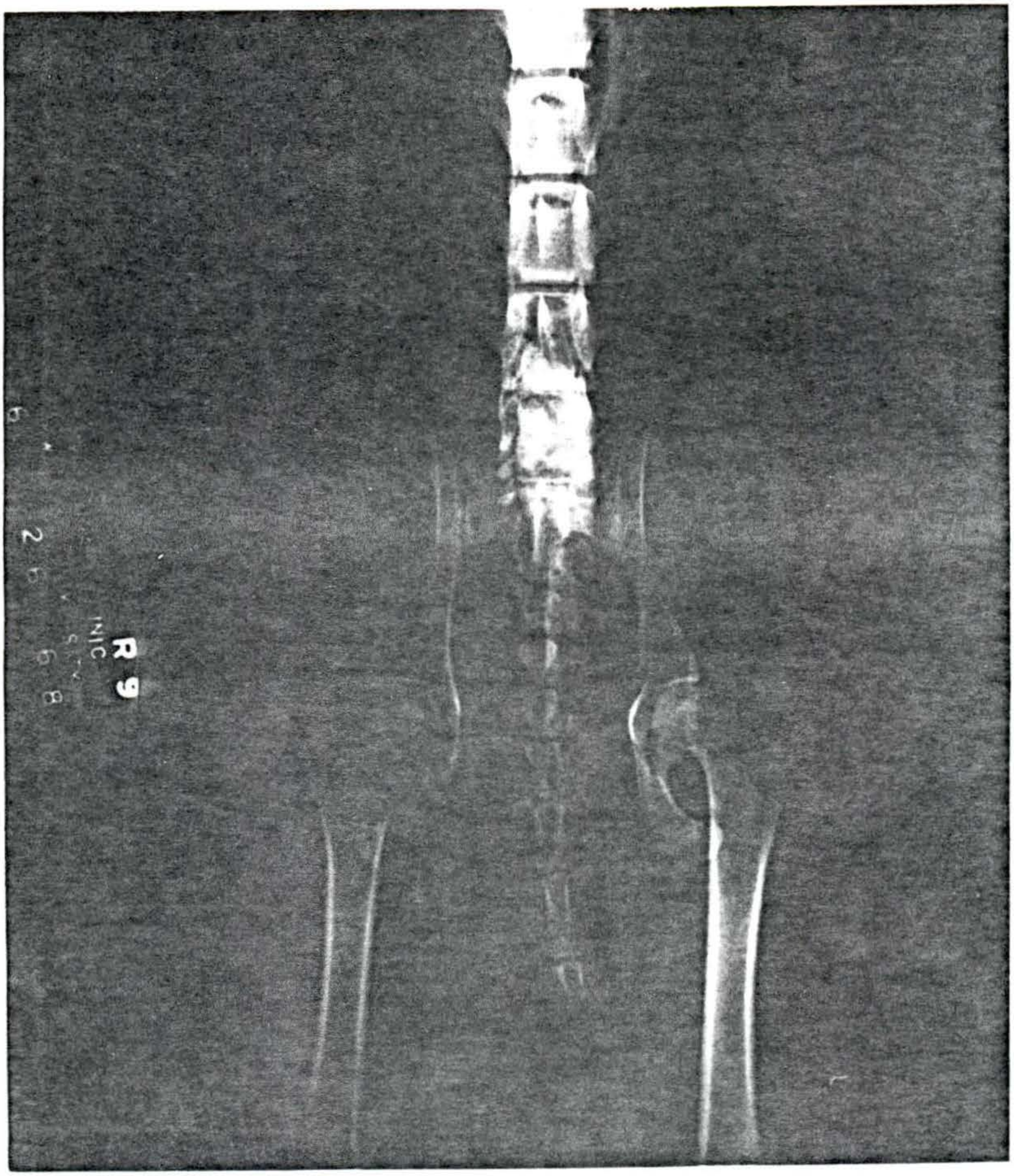


Figure 40. Arthrogram taken 24 hours after injection of Skiodan into the joint capsule of the right hip. Note the contrast medium has evacuated from the urinary bladder and the hip joint looks normal.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